SMALL DIESEL ENGINE

service manual • 2nd edition

Maintain and Repair Small Diesel Engines Up To 160 Cubic Inches (2600cc) Displacement

INTERTEC

SMALL DIESEL ENGINE SERVICE MANUAL

(2nd Edition)

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Dual Dimension

This service manual provides specifications in both the U.S. Customary and Metric (SI) systems of measurement. The first specification is given in the measuring system perceived by us to be the preferred system when servicing a particular component, while the second specification (given in parenthesis) is the converted measurement. For instance, a specification of "0.011 inch (0.28 mm)" would indicate that we feel the preferred measurement, in this instance, is the U.S. system of measurement and the metric equivalent of 0.011 inch is 0.28 mm.

CONTINENTAL

TELEDYNE CONTINENTAL
MOTORS
INDUSTRIAL PRODUCTS
DIVISION

700 Terrace Street
Muskegon, Michigan 49443

Model	No. Cyls.	Bore	Stroke	Displ.
TMD27	4	91 mm (3.58 in.)	103.2 mm (4.06 in.)	2680 cc (163.5 cu. in.)

The Model TMD27 engine is water-cooled, four-cylinder, four-stroke diesel engine. Crankshaft rotation is counter-clockwise at pto end and number 1 cylinder is cylinder nearest pto end of engine. Firing order is 1-3-4-2.

Metric fasteners are used throughout engine.

MAINTENANCE

LUBRICATION

Recommended engine oil is SAE 5W-20 for temperatures between minus 18°C (0°F), SAE 10W for temperatures below minus 18°C (0°F) and 0° (32°F), SAE 20W for temperatures between 0°C (32°F) and 24°C (75°F) and SAE 30 for temperatures above 24°C (75°F). API oil classification should be CC or CD. Oil sump capacity is 5.7 liters (6 quarts) while an additional liter (quart) of oil is contained in the oil filter. Manufacturer recommends renewing oil after every 50 hours of operation.

ENGINE SPEED ADJUSTMENT

Idle speed should be 800-1000 rpm and is adjusted by turning idle speed screw (I – Fig. C1-1). Maximum governed speed is determined by engine application and is adjusted by turning high speed screw (H).

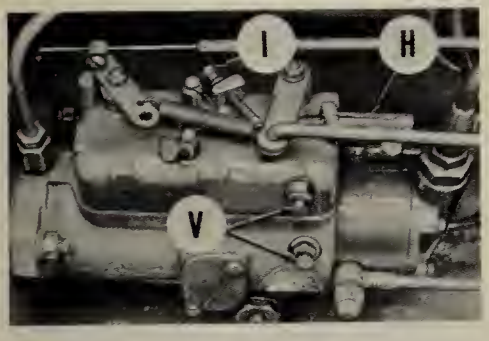


Fig. C1-1—Typical view of fuel injection pump. Loosen vent screws (V) to bleed fuel. Turn screw (I) to adjust idle speed or screw (H) to adjust high speed.

FUEL SYSTEM

FUEL FILTERS. An external fuel filter is mounted on side of engine. Renew fuel filter after every 400 hours of operation or sooner if required.

BLEED FUEL SYSTEM. To bleed fuel system, remove bleed screw on fuel filter body. Allow gravity to force fuel flow or operate priming lever on fuel transfer pump until air-free fuel flows, then reinstall filter body bleed screw. Loosen injection pump bleed screws (V – Fig. C1-1) and operate fuel transfer pump priming lever until air-free fuel flows, then tighten bleed screws (V). Loosen fittings for high pressure injection lines at injectors. Rotate engine crankshaft to operate fuel injection pump until air-free fuel flows from injection lines. Retighten injection lines.

INJECTION PUMP TIMING

The injection pump should be properly timed when timing marks scribed on timing gear cover, adapter plate and pump mounting flange are aligned. Loosen adapter plate and injection pump mounting nuts, then rotate plate or pump as required to align marks.

If timing marks are not present or believed false, rotate engine so number 1 piston is at top dead center on compression. Remove inspection plate on side of injection pump, loosen pump mounting nuts then rotate pump so line "A" on pump drive plate is aligned with flat end of snap ring as shown in Fig. C1-2. It may be necessary to loosen and rotate adapter plate if rotating pump will not align line "A" and snap ring end.

Injection timing should occur at 15-17 degrees before top dead center with engine running at 1600 rpm. Manufacturer recommends using a suitable timing light to set injection timing.

If injection timing cannot be correctly set as outlined previously, refer to INJECTION PUMP section as injection pump gear may be improperly timed.

COOLING SYSTEM

Model TMD27 is liquid cooled and uses a water pump mounted on the engine front to circulate coolant. Corrosion resistant antifreeze or an anticorrosion additive should be used in the engine coolant.

A thermostat is located under the coolant outlet. Thermostat opening temperature is 81°C (180°F).

BELT TENSION

Belt deflection measured midway between water pump and crankshaft pulleys should be approximately 13 mm (½ inch) using thumb pressure. Belt tension is adjusted by repositioning alternator.

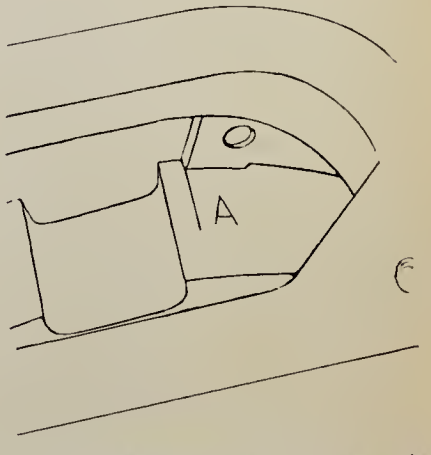


Fig. C1-2—Injection timing is correct when scribed line "A" aligns with snap ring end and number 1 piston is at top dead center on compression.

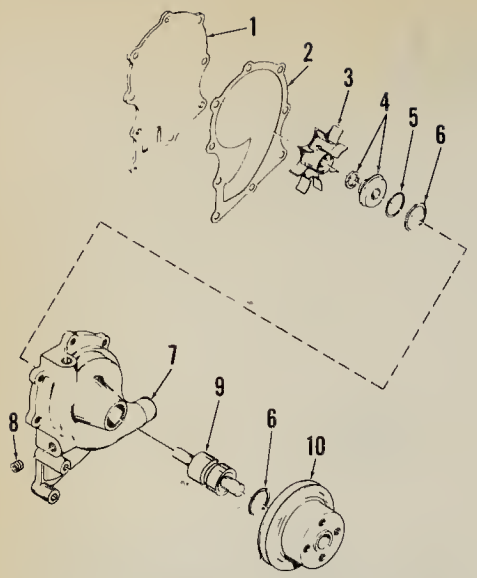


Fig. C1-3—Exploded view of water pump.

1. Cover
2. Gasket
3. Impeller
4. Seal assy.
5. "O" ring
6. Snap ring
7. Pump housing
8. Plug
9. Shaft assy.
10. Pulley

REPAIRS

TIGHTENING TORQUES

Refer to the following table for special tightening torques. All fasteners are metric.

Camshaft nut.....88-95 N·m (65-70 ft.-lbs.)
Connecting rod.....61-68 N·m (45-50 ft.-lbs.)
Crankshaft pulley.....163-176 N·m (120-130 ft.-lbs.)
Cylinder head:
M10.....68-75 N·m (50-55 ft.-lbs.)
M12.....122-129 N·m (90-95 ft.-lbs.)
Flywheel.....68-75 N·m (50-55 ft.-lbs.)
Flywheel housing.....61-68 N·m (45-50 ft.-lbs.)
Glow plug.....31-38 N·m (23-28 ft.-lbs.)
Injection pump gear.....27-34 N·m (20-25 ft.-lbs.)
Injector.....68-75 N·m (50-55 ft.-lbs.)
Main bearing.....150-162 N·m (110-120 ft.-lbs.)
Manifolds:
M8.....20-24 N·m (15-18 ft.-lbs.)
M10.....34-40 N·m (25-30 ft.-lbs.)
Oil pan.....14-19 N·m (10-14 ft.-lbs.)
Oil pump.....20-24 N·m (15-18 ft.-lbs.)

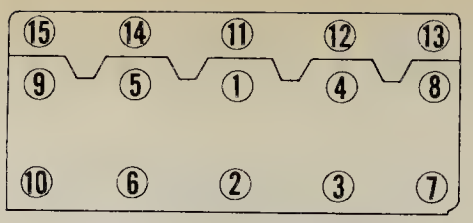


Fig. C1-4—Cylinder head tightening sequence.

Rocker cover.....7-8 N·m (5-6 ft.-lbs.
Rocker arm shaft.....23-27 N·m (17-20 ft.-lbs.)

WATER PUMP

R&R AND OVERHAUL. To remove water pump, drain coolant, disconnect hoses and remove drive belt. Unbolt and remove water pump.

Refer to Fig. C1-3 and disassemble pump as follows: Pull pulley (10) off shaft then remove cover (1). Pull impeller (3) off shaft and remove seal assembly (4). Detach snap rings (6). Drive or press shaft (9) out of housing towards pulley side of pump. Housing will be damaged if shaft is removed from impeller side of pump.

Reverse disassembly procedure for reassembly, however, install pulley (10) before impeller (3). However, do not install cover (1) until pulley (10) is installed so shaft can be supported to prevent damage to bushing and seal.

VALVE ADJUSTMENT

Valve clearance should be adjusted with engine at normal operating temperature. Remove rocker cover for access to rocker arms. Adjust clearance for intake valves to 0.36 mm (0.014 inch) and for exhaust valves to 0.46 mm (0.018 inch).

CYLINDER HEAD AND VALVE SYSTEM

R&R AND OVERHAUL. Drain coolant, then detach coolant hoses. Remove intake and exhaust manifolds. Detach glow plug wire. Disconnect fuel lines from injectors and cap or plug all openings to prevent contamination, then remove injectors. Remove rocker cover and rocker arm shaft assembly. Extract push rods being careful not to dislodge cam followers. Remove cylinder head retaining screws and lift off head.

Maximum allowable head surface warpage is 0.10 mm (0.004 inch) measured lengthwise or 0.075 mm (0.003 inch) measured across head. Precombustion chamber inserts must be flush or project up to 0.076 mm (0.003 inch) above head surface.

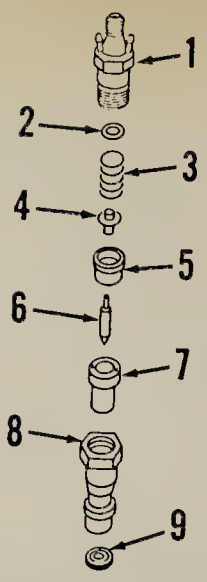


Fig. C1-5—Exploded view of fuel injector.

1. Body
2. Shim
3. Spring
4. Pressure pin
5. Spacer
6. Valve
7. Nozzle
8. Nozzle nut
9. Heat shield

Intake valve face and seat angles are 30° and exhaust valve face and seat angles are 45°. Valve seat width for all valves should be 1.6-3.2 mm (1/16-⅛ inch).

Intake and exhaust valve guide inner diameter is 8.692-8.717 mm (0.342-0.343 inch) and maximum allowable diameter is 8.775 mm (0.345 inch). Intake valve stem diameter is 8.642-8.660 mm (0.3402-0.3409 inch). Intake valve stem clearance in guide should be 0.032-0.075 mm (0.0013-0.0030 inch) with a maximum clearance of 0.125 mm (0.005 inch). Exhaust valve stem diameter is 8.622-8.640 mm (0.3394-0.3401 inch). Exhaust valve stem clearance in guide should be 0.052-0.095 mm (0.0020-0.0037 inch) with a maximum allowable clearance of 0.142 mm (0.0056 inch). Valve guides are renewable. When properly installed, bottom of guide should be 40 mm (1.575 inches) from gasket surface of cylinder head.

Valve spring pressure should be 235 newtons (53 pounds) at 42.0 mm (1.65 inches) and 466 newtons (105 pounds) at 32.88 mm (1.29 inches). Installed spring height is 42.0 mm (1.65 inches).

Maximum allowable clearance between rocker arms and shaft is 0.13 mm (0.005 inch).

Install cylinder head by reversing the removal procedure. Tighten cylinder head screws in three steps following sequence shown in Fig. C1-4. Final torque is 68-75 N·m (50-55 ft.-lbs.) for M10 screws and 122-129 N·m (90-95 ft.-lbs.) for M12 screws. Retorque cylinder head screws with engine at normal operating temperature.

INJECTOR

WARNING: Fuel emerges from injector with sufficient force to penetrate the skin. When testing injector, keep yourself clear of nozzle spray.

REMOVE AND REINSTALL. Before removing an injector or loosening injector lines, thoroughly clean injector, lines and adjacent area with a suitable solvent and compresssed air. Disconnect high pressure and bypass lines from injector, then cap lines to prevent contamination. Unscrew injector from cylinder head, then remove and discard heat sheild (9–Fig. C1-5).

Before installing injector, be sure injector bore and seating surface in head are clean and free of carbon. Install a new heat shield (9). Install injector and tighten 68-75 N·m (50-55 ft.-lbs.) Reconnect injector lines.

TESTING. A complete job of testing and adjusting injectors requires use of special test equipment. Only clean, approved testing oil should be used to test injectors. Injector nozzle should be tested for opening pressure, seat leakage and spray pattern.

When operating properly during test, injector nozzle will emit a buzzing sound and cut off quickly with no fluid leakage at seat.

Before conducting test, operate tester lever until test oil flows, then attach injector. Close valve to tester gage and pump tester lever a few quick strokes to be sure nozzle valve is not stuck, which would indicate that injector may be serviceable without disassembly.

OPENING PRESSURE. Open valve to tester gage and operate tester lever slowly while observing gage reading. Opening pressure should be 13000-13500 kPa (1885-1960 psi).

Opening pressure is adjusted by varying thickness of shim (2–Fig. C1-5).

SEAT LEAKAGE. Injector nozzle tip should not leak at a pressure less than 10800 kPa (1560 psi). To check for leakage, actuate tester lever slowly and as gage needle approaches suggested test pressure, observe nozzle tip. Hold pressure for 10 seconds; if drops appear or nozzle tip becomes wet, valve is not seating and injector must be disassembled and overhauled as later outlined.

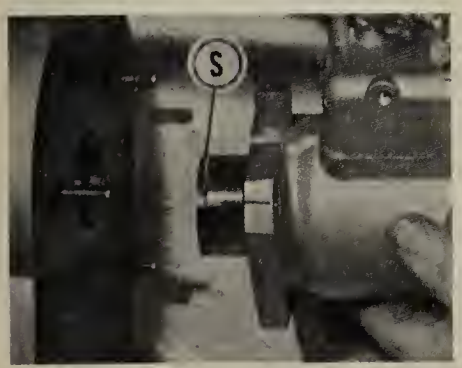


Fig. C1-6—View of slot (S) which must engage pin in pump gear.

SPRAY PATTERN. Spray pattern should be well atomized and slightly conical, emerging in a straight axis from nozzle tip. If pattern is wet, ragged or intermittent, nozzle must be overhauled or renewed.

OVERHAUL. Hard or sharp tools, emery cloth, grinding compound or other than approved solvents or lapping compounds must never be used. An approved nozzle cleaning kit is available through a number of specialized sources.

Wipe all dirt and loose carbon from exterior of nozzle and holder assembly. Refer to Fig. C1-5 for exploded view and proceed as follows:

Secure injector body (1) in a soft jawed vise or holding fixture and remove nozzle nut (8). Place all parts in clean calibrating oil or diesel fuel as they are removed, using a compartmented pan and using extra care to keep parts from each injector together and separate from other units.

Clean exterior surfaces with a brass wire brush, soaking in an approved carbon solvent, if necessary, to loosen hard carbon deposits. Rinse parts in clean diesel fuel or calibrating oil immediately after cleaning to neutralize the solvent and prevent etching of polished surfaces. Tighten nozzle nut (8) to 68-75 N·m (50-55 ft.-lbs.) when installing on injector body (1).

GLOW PLUGS

Each cylinder is equipped with a glow plug. Glow plugs are connected in parallel with each glow plug grounded through mounting threads. Before suspecting a glow plug malfunction, determine that current is reaching glow plugs. Tighten glow plugs to 31-38 N·m (23-38 ft.-lbs.).

INJECTION PUMP

REMOVE AND REINSTALL. To remove injection pump, disconnect fuel lines and cap openings to prevent contamination. Remove pump adapter plate retaining nuts and remove injection pump.

The injection pump should be tested and overhauled by a shop qualified in diesel injection pump repair.

Proceed as follows to assemble pump, adapter plate and gear and install pump on engine: Place adapter plate on pump and loosely install pump retaining nuts.

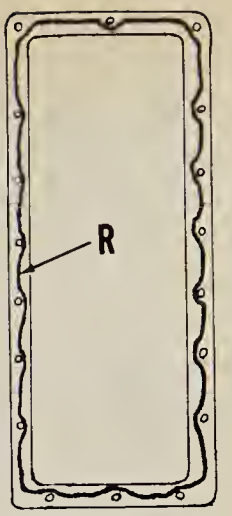


Fig. C1-7—Apply RTV form-in-place gasket in a 2 mm (3/32 inch) bead (R) to oil pan flange as shown.

Install pump gear on pump shaft so pin in gear hub mates with slot (S–Fig. C1-6) in pump shaft. Tighten gear retaining screws to 27-34 N·m (20-25 ft.-lbs.). Rotate engine crankshaft so number 1 piston is at top dead center on compression–beveled tooth on pump drive gear (behind camshaft gear) should be centered in opening in rear of timing gear case. Unscrew plug in front of timing gear cover and install a timing pin. Install injection pump so pump gear mates with drive gear and aligns with timing pin. Refer to INJECTION PUMP TIMING section and time pump.

OIL PAN

The oil pan is sealed by RTV form-in-place gasket. Apply a 2 mm (3/32 inch) bead of gasket material as shown in Fig. C1-7. Gasket surfaces of oil pan and crankcase must be clean and dry before applying gasket material.

PISTON AND ROD UNITS

REMOVE AND REINSTALL. Piston and connecting rod are removed as a unit after removing cylinder head and oil pan. If not present, make marks on rod and cap for reassembly. Unscrew rod cap retaining screws, detach rod cap and extract piston and rod.

When assembling piston and rod, piston pin installation is easier if the piston is heated prior to pin insertion. Install piston and rod assembly so notch (N–Fig. C1-8) is towards water pump end of engine. Tighten connecting rod screws to 61-68 N·m (45-50 ft.-lbs.).

PISTON, PIN AND RINGS

All pistons are equipped with two compression rings and an oil control ring. The piston pin is fully floating in piston and rod.

INJECTORS

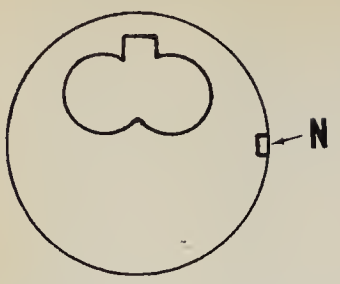


Fig. C1-8—Install piston so notch (N) in piston crown is towards water pump end of engine.

Piston clearance is measured using a 13 mm (½ inch) wide, 0.08 mm (0.003 inch) thick feeler gage and a suitable pull scale. Invert the piston, keeping pin bore parallel to crankpin, and insert piston with feeler gage 90° from pin bore into cylinder until piston skirt is approximately 50 mm (2 inches) into cylinder bore. Slowly withdraw feeler gage with the pull scale and note scale reading. Piston fit is correct when 2.3-4.5 kg (5-10 pounds) pull is required to withdraw feeler gage.

Piston ring end gap should be 0.40-0.65 mm (0.016-0.025 inch) for compression rings and 0.30-0.60 mm (0.012-0.024 inch) for the oil control ring. Piston ring side clearance for all rings should be 0.050-0.082 mm (0.002-0.003 inch).

Piston pin diameter is 28.571-28.575 mm (1.1249-1.1250 inches) with a maximum wear limit of 28.562 mm (1.1245 inches). Piston pin bore in piston should be 28.578-28.583 mm (1.1251-1.1253 inches). Piston pin clearance in connecting rod should be 0.013-0.028 mm (0.0005-0.0011 inch).

CONNECTING ROD AND BEARINGS

Connecting rod is equipped with a renewable bushing in the small end and insert type bearings in the big end.

Clearance between rod bearing and crankpin should be 0.016-0.080 mm (0.0006-0.0031 inch). Maximum bearing clearance is 0.091 mm (0.0036 inch). Standard crankpin diameter is 49.187-49.212 mm (1.9365-1.9375 inches). Rod side play should be 0.15-0.28 mm (0.006-0.011 inch).

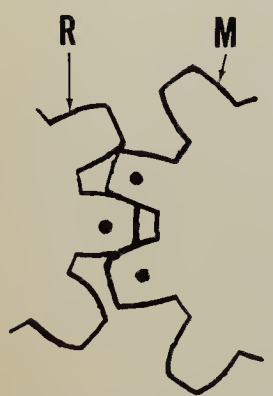
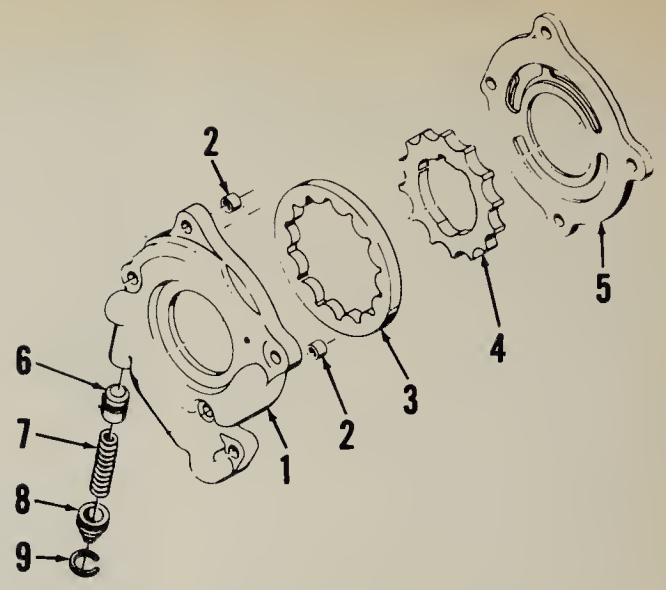


Fig. C1-9—Diagram showing crankshaft (R) and camshaft (M) timing gear marks.

Fig. C1-10—Exploded view of oil pump.

1. Pump body
2. Hollow dowel
3. Outer gear
4. Inner gear
5. Cover
6. Pressure relief valve
7. Spring
8. Plug
9. Snap ring



The small end bushing inner diameter is 30.150-30.175 mm (1.187-1.188 inches). Install bushing so oil holes are aligned then, if necessary, ream to desired diameter.

CAMSHAFT AND CAM FOLLOWERS

R&R AND OVERHAUL. Remove water pump belt and crankshaft pulley. Remove cylinder head as previously outlined. Remove timing gear cover (note that oil pan is attached to timing gear cover). Unscrew camshaft nut, then use suitable pullers to slide camshaft gear and injection pump gear off end of camshaft. Remove cam followers, camshaft retainer plate and camshaft.

Diameter of camshaft bearing journal nearest gear end is 47.511-47.536 mm (1.8705-1.8715 inches) while diameter of bearing journal at opposite end is 42.748-42.774 mm (1.6830-1.6840 inches). Center bearing journal diameter is 44.336-44.361 mm (1.7455-1.7465 inches). Camshaft bearing clearance should be 0.064-0.114 mm (0.0025-0.0045 inch). Cam follower outside diameter is 25.311-25.324 mm (0.9965-0.9970 inch). Maximum allowable cam follower clearance is 0.13 mm (0.005 inch).

Reverse camshaft removal procedure for installation while noting the following: Align crankshaft and camshaft gear marks shown in Fig. C1-9. Insert a suitable bar through the fuel transfer pump opening in cylinder block to prevent camshaft movement from knocking out rear expansion plug while driving injection pump gear and camshaft gear onto camshaft. Do not attempt to force gears onto camshaft with camshaft nut as camshaft end may break. Tighten camshaft nut 88-95 N·m (65-70 ft.-lbs.). Camshaft end play should be 0.038-0.175 mm (0.0015-0.0069 inch) and is maintained by a thrust plate located between the camshaft retainer and cylinder block. Renew thrust plate if end play is excessive.

OIL PUMP

R&R AND OVERHAUL. To remove oil pump, remove water pump belt and crankshaft pulley. Remove oil pan and timing gear cover. Unscrew camshaft nut, then use a suitable puller to remove camshaft and crankshaft gears. Unscrew oil pickup bracket, then remove oil pump.

Remove cover (5—Fig. C1-10) and inspect gears and pump body for excessive wear or damage. The oil pressure relief valve is accessible after removing snap ring (9). Be sure "O" ring located between pickup tube and pump body seals properly. If oil pickup screen is renewed, position new screen on pickup bowl so lead disc is directly across from pickup tube opening.

Reverse removal procedure for installation. Tighten oil pump mounting screws to 20-24 N·m (15-18 ft.-lbs.) Refer to CAMSHAFT AND CAM FOLLOWERS section when installing camshaft gear. Refer to OIL PAN section for oil pan installation.

FLYWHEEL AND FLYWHEEL HOUSING

The flywheel housing is secured to the cylinder block by special cap screws in the upper holes which have sealing bands. Failure to use these special cap screws will result in oil leakage. Flywheel runout should not exceed 0.20 mm (0.008 inch). Tighten flywheel hous-

ing screws to 61-68 N·m (45-50 ft.-lbs.) and flywheel screws to 68-75 N·m (50-55 ft.-lbs.).

REAR CRANKSHAFT SEAL

REMOVE AND REINSTALL. The rear crankshaft seal may be removed and installed without removing crankshaft. To remove rear crankshaft seal, remove flywheel, flywheel housing and oil pan. Remove rear main bearing cap and remove seal halves from cap and block.

To install seal, lubricate seal lip, apply a light grease to back of seal half and carefully slide seal into position in block with lip pointing towards engine. Install seal half in rear main bearing cap with lip towards engine.

To install rear main bearing cap, apply a light coat of RTV sealer to surface (S–Fig. C1-11) of bearing cap. Install rear main bearing cap in cylinder block and tighten cap screws to 150-162 N·m (110-120 ft.-lbs.). Inject RTV sealer into bearing cap cavities (C) until sealer is expelled from bottom corners. Be sure cavity is full. Insert side seals (E) into cavities (C) so ends are flush with bottom surface of cylinder block then wipe away excess sealer.

Install oil pan and flywheel as previously outlined.

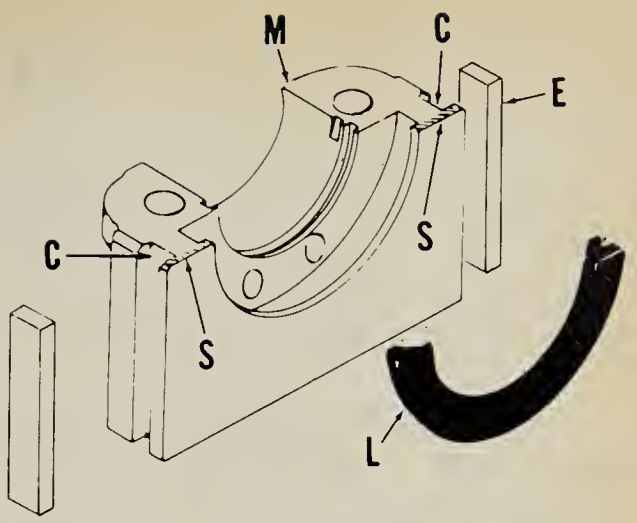


Fig. C1-11—Refer to text for installation of rear crankshaft seal (L) and rear main bearing cap (M).

CRANKSHAFT AND BEARINGS

R&R AND OVERHAUL. To remove crankshaft, remove oil pump, pistons and rods, and flywheel as previously outlined. The crankshaft can be removed after detaching main bearing caps.

Main bearing journal diameter is 72.944-72.974 mm (2.8718-2.8730 inches) and main bearing clearance should be 0.058-0.133 mm (0.0023-0.0052 inch). Crankshaft end play should be 0.04-0.17 mm (0.0016-0.0067 inch) with a maximum allowable limit of 0.18 mm (0.007 inch). End play is controlled by center main bearing.

Tighten main bearing cap screws to 150-162 N·m (110-120 ft.-lbs.). Refer to REAR MAIN BEARING SEAL section for proper installation of rear main bearing cap.

DEUTZ

7585 Ponce de Leon Circle
Atlanta, Georgia 30340

Model	No. Cyls.	Bore	Stroke	Displ.
F1L 208 D	1	80 mm (3.150 in.)	82 mm (3.228 in.)	413 cc (25.2 cu. in.)
F1L 210 D	1	95 mm (3.740 in.)	95 mm (3.740 in.)	673 cc (41.0 cu. in.)

These engines are air-cooled, four-stroke, direct injection diesels. Crankshaft rotation is counterclockwise when facing flywheel.

MAINTENANCE

LUBRICATION

Crankcase oil must meet or exceed API service classification CC or CD. The oil viscosity grade is determined by the ambient temperature expected between oil changes. For operation in temperatures below −5° (23°F), SAE 10W oil is recommended. For temperatures ranging between −10°C (14°F) to 10°C (50°F), SAE 20W-20 should be used. When temperatures are between 5°C (40°F) to 30°C (85°F), SAE 30 oil is recommended. For temperature above 25°C (77°F), SAE 40 oil should be used. Multiviscosity oil, such as 20W-40, is approved for all temperature operation, however, the oil must meet MIL-L46152 specification.

Manufacturer recommends governing oil change intervals on oil grade used (CC or CD), operating conditions (normal or severe) and sulfur content of fuel (above or below 0.5%). On all new or overhauled engines, first oil change should be after the first 20-30 hours of operation for severe duty applications or after the first 40-60 hours of operation for normal duty applications. Then, the second oil change is performed at the normal interval for all engines as follows: For normal duty operation and using fuel with less than 0.5% sulfur content, oil change interval is every 200 hours for "CC' classification oil or every 300 hours for "CD" oil. If fuel sulfur content exceeds 0.5% interval is reduced to every 100 hours for "CC" oil or every 200 hours for "CD" oil. For engines used in severe duty applications and using fuel with less than 0.5% sulfur content, oil change interval is every 100 hours of operation when using "CC" oil or every 200 hours if using "CD" oil. If fuel sulfur content exceeds 0.5%, use of "CC" oil is not recommended for severe duty applications. Oil change interval using "CD" oil is reduced to 100 hours of operation. In all applications regardless of hours of operation, oil should be changed at least once every 12 months.

Engine oil should be drained while engine is warm. Crankcase capacity is approximately 2.1 liters (2.2 quarts) for F1L 208 D and 2.4 liters (2.5 quarts) for F1L 210 D. Engine filter should be renewed at the same time oil is changed.

AIR CLEANER

The oil bath type air cleaner should be service after every 10 to 60 hours of operation depending on dust conditions. Engine should be stopped at least one hour before removing filter bowl to allow oil to drain from filter element into bowl. Clean bowl and refill with clean oil to the oil level mark. If filter element is heavily contaminated, it should be removed and cleaned in diesel fuel. Allow diesel fuel to drain out of filter before reinstalling.

FUEL SYSTEM

FUEL FILTER AND BLEEDING. On engines equipped with a fuel tank mounted on the engine, a renewable filter element is mounted internally in bottom of tank. It is recommended that filter element be renewed after every 200 hours of operation. Fuel should be drained from tank before removing filter.

On engines using a remote mounted fuel tank, an externally mounted fuel filter is used. Manufacturer recommends renewing filter after every 1200 hours of operation or sooner if loss of power is evident.

Whenever fuel filter is serviced or fuel lines are disconnected, air must be bled from fuel system in the following manner. If equipped with external type filter, loosen bleed screw (1−Fig. D1-1) on filter mounting bracket. When air-free fuel flows from bleeder, retighten screw. On all engines, loosen bleed screw (2−Fig. D1-2) on injection pump. When air-free fuel flows from bleeder, retighten screw. If engine fails to start at this point, loosen high pressure fuel line at injector. With pump controls in "run" position, crank engine until fuel is discharged at loosened connection. Retighten fuel line fitting and start engine.

ENGINE SPEED ADJUSTMENT. The engine must be at normal operating

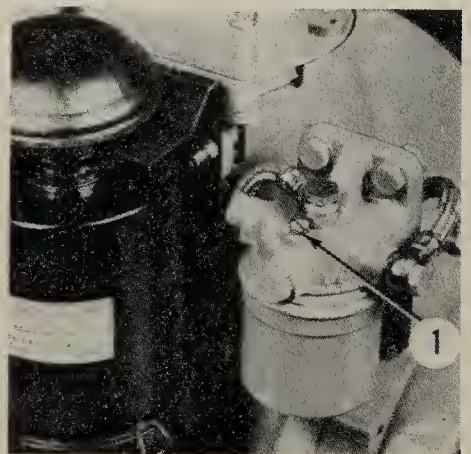


Fig. D1-1—View of air bleed screw (1) on filter housing (if so equipped).

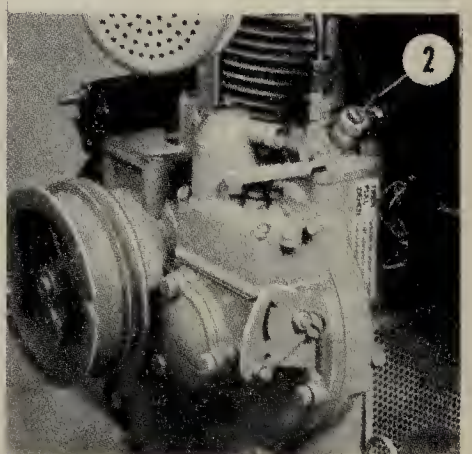


Fig. D1-2—View of injection pump air bleed screw (2).

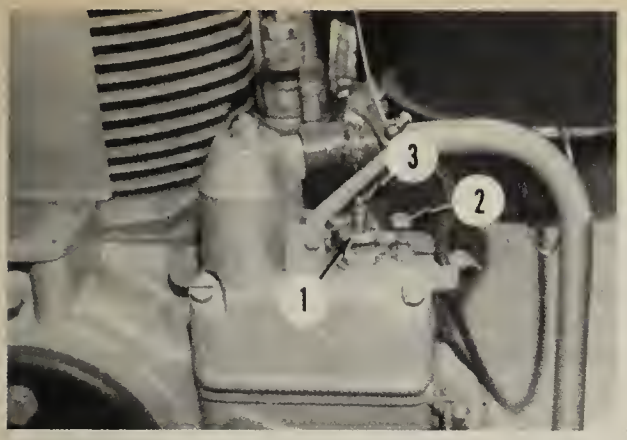


Fig. D1-3—Idle speed is adjusted using screw (1) and maximum speed is adjusted using screw (2). Be sure governor rod (3) moves freely.

temperature and an accurate tachometer used when adjusting engine speed setting. The engine speed settings depend on the engine application. Recommended engine speed should be stamped on the engine nameplate.

Low idle speed is normally 800-1000 rpm. Idle speed is adjusted using adjusting screw (1 – Fig. D1-3). Note that some engines are not equipped with a low idle adjusting screw.

Maximum speed is adjusted using adjusting screw (2). Maximum rated speed must not exceed 3600 rpm on F1L 208 D engine or 3000 rpm on F1L 210 D engine. Be sure to install a new seal wire on maximum speed screw to secure adjustment.

INJECTION PUMP TIMING. To check injection pump static timing, first turn crankshaft in normal direction until piston is on compression stroke. Disconnect fuel inlet pipe and injector high pressure pipe from injection pump. Connect a nozzle tester pump to fuel inlet of injection pump and attach a drip tube to high pressure outlet of pump. Move speed control lever to full-speed position. Do not actuate excess fuel starting button. Actuate tester pump and note that fuel should flow from drip tube. Slowly rotate crankshaft until fuel flow from injection pump outlet just stops. AT this point beginning of injection occurs, and timing marks on crankshaft pulley and front cover should be aligned as shown in Fig. D1-4.

Injection timing is adjusted by changing thickness of pump mounting shims. Reducing shim thickness will advance timing and increasing shim thickness will retard timing.

REPAIRS

TIGHTENING TORQUES

Refer to the following table for special tightening torques. Metric fasteners are used throughout the engine.

Connecting rod:	
F1L 208 D	35 N·m (26 ft.-lbs.)
F1L 210 D	45 N·m (33 ft.-lbs.)
Cylinder head:	
F1L 208 D	40 N·m (30 ft.-lbs.)
F1L 210 D	55 N·m (40 ft.-lbs.)
Crankshaft pulley	40 N·m (30 ft.-lbs.)
Flywheel:	
F1L 208 D	160 N·m (118 ft.-lbs.)
F1L 210 D	180 N·m (133 ft.-lbs.)
Front cover	23 N·m (17 ft.-lbs.)
Injection pump	23 N·m (17 ft.-lbs.)
Injector	35 N·m (26 ft.-lbs.)
Main bearing flange	35 N·m (26 ft.-lbs.)
Oil sump	23 N·m (17 ft.-lbs.)
Rocker arm bracket	30 N·m (22 ft.-lbs.)
Rocker cover	23 N·m (17 ft.-lbs.)

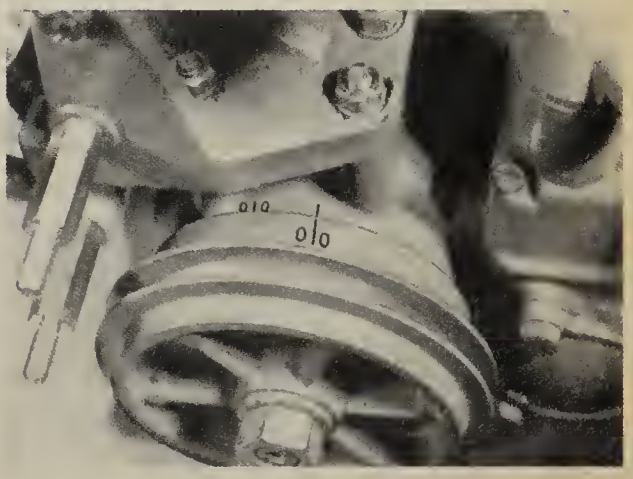


Fig. D1-4—At beginning of injection, timing marks should be aligned as shown.

COMPRESSION PRESSURE

Compression pressure may be checked to establish relative condition of engine before proceeding with engine disassembly. Engine should be run briefly to ensure there is a normal fill of oil on rings and cylinder before checking pressure. Remove injector and install Deutz special adapter 100 080 with pressure gage. Cranking speed must be at least 150 rpm. Compression pressure should be 1900-2100 kPa (275-305 psi).

VALVE ADJUSTMENT

Valve clearance should be adjusted with engine cold. Recommended clearance is 0.15 mm (0.006 inch) for intake and 0.20 mm (0.008 inch) for exhaust.

To adjust clearance, remove rocker cover and rotate crankshaft until piston is at TDC on compression stroke. Loosen rocker arm adjusting screw locknut. Turn adjusting screw as required until appropriate size feeler gage can be inserted between valve and rocker arm with a slight drag. Tighten locknut and recheck clearance.

On hand-start engines, a decompression device is fitted to cylinder head to partially open the intake valve during engine starting. With intake valve closed and decompression device in disengaged position, measure clearance between stop pin of rocker arm and decompressor cam with a feeler gage. Clearance should be 0.7 mm (0.027 inch). If necessary, adjust stop pin to obtain desired clearance. To check decompressor operation, measure distance from rocker arm to top of rocker arm housing with decompressor engaged and disengaged. The difference between the two readings is distance valve is being opened which should be 0.4-0.6 mm (0.016-0.023 inch).

CYLINDER HEAD AND VALVE SYSTEM

To remove cylinder head, first remove fuel tank (if equipped), air cleaner and exhaust pipe. Remove injector pipe and injector. Remove rocker cover, rocker arm bracket and push rods. Remove stud nuts and lift off cylinder head. Remove valves from cylinder head and inspect all parts for wear or other damage. Cylinder head is equipped with renewable valve seat inserts and valve guides. Refer to Fig. D1-5.

Valve face and seat angles are 45° for intake and exhaust. Renew valve if head margin is less than 0.7 mm (0.027 inch). Refer to the following table for valve and valve guide dimensions.

F1L 208 D

Intake:
Valve stem OD.....6.953-6.975 mm (0.2737-0.2746 inch)
Valve guide ID.....7.00-7.015 mm (0.2756-0.2762 inch)
Clearance-desired...0.025-0.062 mm (0.0010-0.0024 inch)
Wear limit.....0.12 mm (0.005 inch)

Exhaust:
Valve stem OD.....6.938-6.960 mm (0.2732-0.2740 inch)
Valve guide ID.....7.00-7.015 mm (0.2756-0.2762 inch)
Clearance-desired...0.040-0.077 mm (0.0016-0.0030 inch)
Wear limit.....0.15 mm (0.006 inch)

F1L 210 D

Intake:
Valve stem OD.....7.953-7.975 mm (0.3131-0.3140 inch)
Valve guide ID.....8.00-8.015 mm (0.3150-0.3155 inch)
Clearance-desired...0.025-0.062 mm (0.0010-0.0024 inch)
Wear limit.....0.12 mm (0.005 inch)

Exhaust:
Valve stem OD.....7.938-7.960 mm (0.3125-0.3134 inch)
Valve guide ID.....8.00-8.015 mm (0.3150-0.3155 inch)
Clearance-desired...0.040-0.077 mm (0.0016-0.0030 inch)
Wear limit.....0.15 mm (0.006 inch)

Valve guides should have an interference fit in cylinder head bores of 0.027-0.055 mm (0.001-0.002 inch). Guides with 0.02 mm (0.0008 inch) oversize outside diameter are available for F1L 210 D engines. Use suitable tools to remove and install valve guides. Cylinder head should first be heated to 240°-260°C (465°-500°F). Press new guides in until snap ring contacts cylinder head surface. Be sure guides are installed with chamfered end facing outward. After installation, guide bore must be reamed to provide recommended clearance for valve stem.

NOTE: When renewing valve guides and valve seat inserts, both operations should be performed together so cylinder head is heated only once.

When renewing valve seat inserts, suitable tools must be used to avoid damage to cylinder head. Grind valve seats to obtain recommended valve seating width of 0.8-1.0 mm (0.031-0.039 inch). Maximum allowable seat width is 1.5 mm (0.059 inch).

Install valves and measure distance top of valve head is recessed below surface of cylinder head. Distance should be 0.8-1.0 mm (0.031-0.039 inch) with a maximum limit of 2.0 mm (0.079 inch). If recession is excessive, renew valve seat. If recession is less than specified, grind valve seat as necessary.

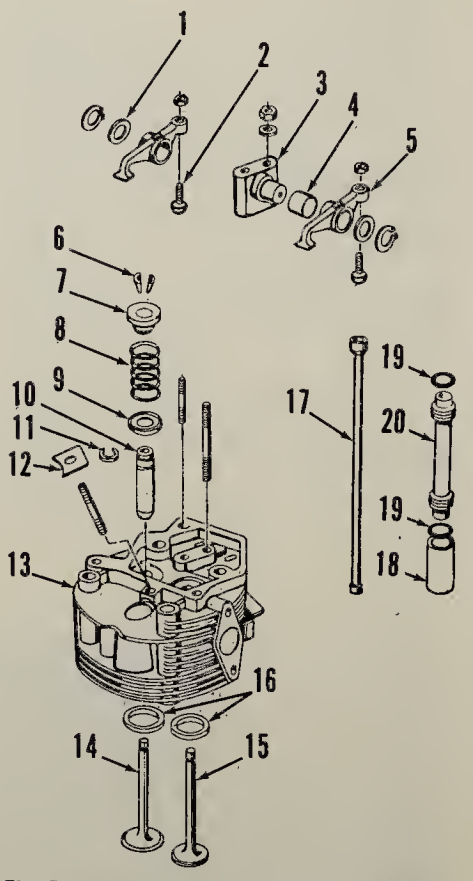


Fig. D1-5—Exploded view of cylinder head and valve system

1. Washer
2. Adjusting screw
3. Rocker arm bracket
4. Bushing
5. Rocker arm
6. Valve keepers
7. Spring retainer
8. Valve spring
9. Spring seat
10. Valve guide
11. Snap ring
12. Injector retainer plate
13. Cylinder head
14. Intake valve
15. Exhaust valve
16. Valve seat inserts
17. Push rod
18. Cam follower
19. Gasket
20. Push rod tube

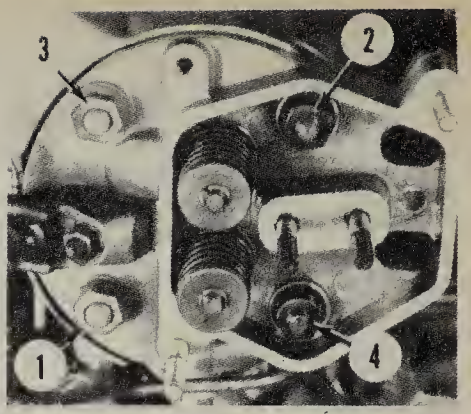


Fig. D1-6—Tighten cylinder head stud nuts in steps following sequence shown.

Check valve springs for distortion, sign of overheating and other damage. Spring free length should be 44.1-44.5 mm (1.736 inches) for F1L 208 D engine and minimum allowable length is 42 mm (1.653 inches). On F1L 210 D engine, spring free length should be 51.3-51.7 mm (2.020-2.035 inches) and minimum allowable length is 49 mm (1.929 inches).

To reinstall cylinder head, reverse the removal procedure. Be sure push rod cover tubes are properly seated. Tighten cylinder head stud nuts in steps following sequence shown in Fig. D1-6. Final tightening torque is 40 N·m (30 ft.-lbs.) for F1L 208 D or 55 N·m (40 ft.-lbs.) for F1L 210 D.

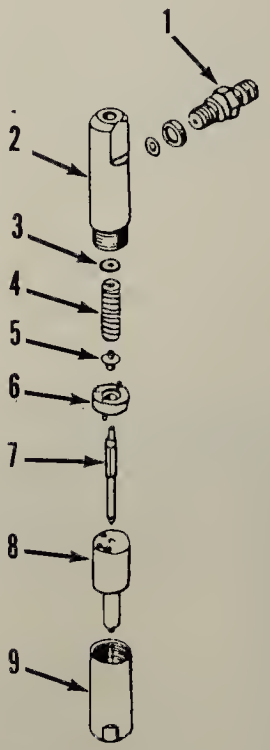


Fig. D1-7—Exploded view of injector assembly.

1. High pressure inlet
2. Injector body
3. Shim
4. Spring
5. Spring seat
6. Spacer
7. Nozzle needle
8. Nozzle body
9. Nozzle nut

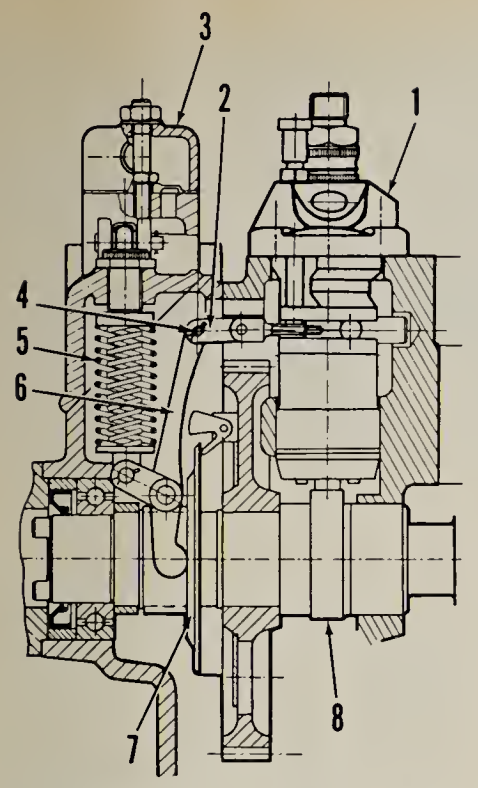


Fig. D1-8—Cross-sectional view of injection pump and governor assembly.

1. Injection pump
2. Fork
3. Governor cover
4. Pin
5. Governor springs
6. Governor lever
7. Governor plate
8. Camshaft

INJECTOR

R&R AND OVERHAUL. Before removing injector, thoroughly clean injector and surrounding area. Immediately plug all openings as fuel lines are disconnected. Be sure to remove seal washer from cylinder head bore after injector is removed.

Be sure to renew copper seal washer when reinstalling injector. Tighten injector clamp nut to 35 N·m (26 ft.-lbs.).

To disassemble injector, secure body (2–Fig. D1-7) in a vise. Remove nozzle nut (9), then withdraw nozzle valve, spacer, spring and shims.

Clean exterior surfaces with a brass wire brush. It may be necessary to soak parts in an approved carbon solvent to loosen hard carbon deposits. Rinse parts in clean diesel fuel after cleaning with solvent. Be sure nozzle needle (7) moves smoothly in nozzle body (8). When needle is pulled about halfway out of body and then released, it should slide down to its seat from its own weight. If needle sticks, reclean or renew nozzle valve assembly.

When reassembling injector, all parts should be wet with diesel fuel. Check injector operation as outlined in TESTING paragraph.

TESTING. A complete job of testing and adjusting injector requires use of special test equipment. Injector should be checked for opening pressure, seat leakage and spray pattern.

WARNING: Fuel emerges from injector with sufficient force to penetrate the skin. When testing injector, keep yourself clear of nozzle spray.

Connect injector to test pump, then operate tester lever several quick strokes to purge air from the injector and to make sure nozzle valve is not stuck. Then operate tester lever slowly while observing tester gage. Nozzle opening pressure should be 19000-22000 kPa (2755-3190 psi). Opening pressure is adjusted by increasing or decreasing thickness of shims (3–Fig. D1-7).

To check nozzle for leakage, operate tester lever slowly to maintain pressure at about 2750 kPa (400 psi) below opening pressure and observe nozzle tip for leakage. If a drop forms on nozzle tip within a 10 second period, nozzle valve is not seating and must be overhauled or renewed. A slight wetness at tip is allowable if a drop does not form.

Operate tester lever several quick strokes (about one stroke per second) and check spray pattern. Spray should be uniform, well atomized and form a cone shape. Nozzle should produce a buzzing sound when operating properly.

INJECTION PUMP

A CIPA injection pump is used on all engines. It is recommended that injection pump be tested and serviced only by a shop qualified in diesel fuel injection repair.

To remove injection pump, remove fuel lines from pump and immediately plug all openings. Remove governor housing cover and lift out governor inner and outer springs (5–Fig. D1-8). Disconnect governor arm (6) from fork (2), then screw fork out and move pump control rack to center position. Remove pump retaining nuts and lift out pump. Retain pump mounting shims for use in reassembly.

To reinstall injection pump, proceed as follows: If original pump shim pack is not available or if a new pump is being installed, place mounting gasket on crankcase and measure distance from surface of gasket to base circle of pump cam. Compare measurement with dimension scribed on pump body and assemble shim pack to obtain the required dimension. The distance with gasket and shims in place cannot be smaller than 82.6 mm (3.252 inches). Install pump and tighten nuts to 23 N·m (17 ft.-lbs.). Turn in fork (2–Fig. D1-9) and connect governor arm (6). Press governor plate (7) forward and check governor lever play (P) at pin (4). Adjust fork in or out to provide 0.2-0.4 mm (0.008-0.016 inch) free play at pin. Reinstall springs and governor cover. Bleed air from fuel system and check injection pump static timing. Check engine speed settings and adjust if necessary.

TIMING GEARS AND FRONT COVER

To remove engine front cover, remove governor cover (3–Fig. D1-8) and lift out governor springs (5). Disconnect governor lever (6) from fork (2). Remove governor pivot shaft and lift out governor lever. Remove front pulley. Remove camshaft cover and balance weight cover with shims. Remove front cover mounting screws, then use a suitable puller to withdraw cover with bearings. Heat cover before tapping out bearings.

Inspect gears for excessive wear and other damage. To remove balance weight and bearing, use a suitable slide hammer puller to remove balancer assembly (2–Fig. D1-10) from crankcase. Remove crankshaft gear retaining ring, then use a suitable puller to pull gear (3) off crankshaft. Refer to

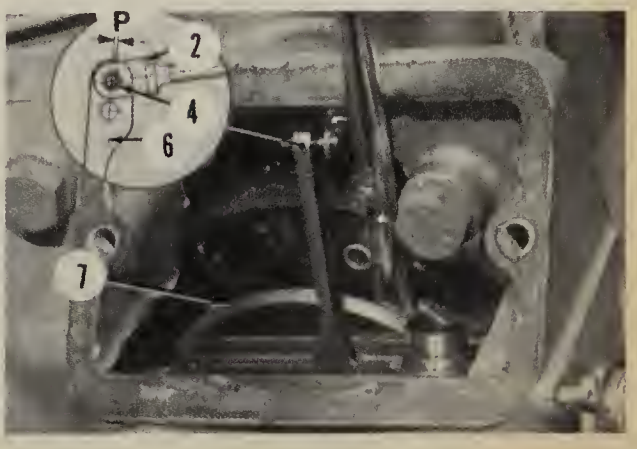


Fig. D1-9—When reconnecting governor linkage, adjust yoke (2) to provide 0.2-0.4 mm (0.008-0.016 inch) end play (P) at governor lever pin (4).

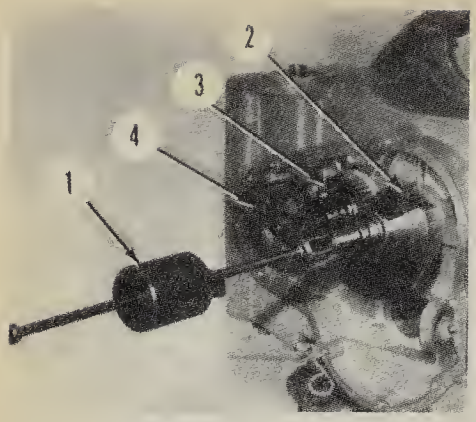


Fig. D1-10—Use a slide hammer puller to remove balance weight assembly.

1. Slide hammer puller
2. Balance weight assy.
3. Crankshaft gear
4. Oil pump gear

CAMSHAFT section for removal of camshaft gear. Remove oil pump gear (4) retaining nut and withdraw gear.

To reinstall gears, proceed as follows: Heat crankshaft gear to about 150°C (300°F) before reinstalling. Heat bearings before installing onto balance weight shaft and camshaft. Make certain timing marks (Fig. D1-11) on crankshaft gear (1), balance weight gear (2) and camshaft gear (3) are aligned as shown. Install oil pump drive gear (1–Fig. D1-12) and check for specified backlash of 0.10-0.15 mm (0.004-0.006 inch) between crankshaft gear and oil pump gear. To adjust backlash, loosen pump mounting cap screws and rotate pump housing in crankcase as necessary. Tighten pump mounting screws to 10 N·m (8 ft.-lbs.). Tighten oil pump drive gear nut to 23 N·m (17 ft.-lbs.).

Heat front cover slightly before reinstalling. Tighten mounting screws to 23 N·m (17 ft.-lbs.). Check and adjust balance weight and camshaft end play as follows: Measure distance (A–Fig. D1-13) from surface of front cover to race of ball bearing. Measure distance (B–Fig. D1-15) of bearing retainer with

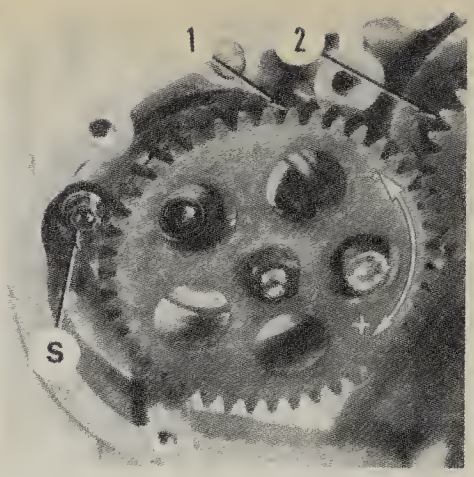


Fig. D1-12—To adjust backlash between oil pump drive gear (1) and crankshaft gear (2), loosen pump mounting screws and rotate pump in crankcase. Note position of small head pump mounting screw (S).

gasket in place as shown. Distance "A" must be 0.15-0.20 mm (0.006-0.008 inch) larger than distance "B". If the distance is too large, install shims between bearing retainer and bearing. If the distance is too small, install thicker gasket between bearing retainer and front cover. Tighten bearing retainer cap screws to 23 N·m (17 ft.-lbs.). Camshaft end play is determined in the same manner by measuring from surface of front cover to race of bearing (A–Fig. D1-14) and subtracting bearing retainer dimension (B–Fig. D1-15). The difference must be within range of 0.15-0.20 mm (0.006-0.008 inch). Adjustment procedure is the same as that for balance weight shaft. Tighten camshaft cover mounting screws to 23 N·m (17 ft.-lbs.). Complete installation by reversing the removal procedure.

CAMSHAFT

To remove camshaft, first remove cylinder head, push rods, cam follower retainer plate and cam followers. Remove injection pump and engine front cover as previously outlined. Remove camshaft assembly from crankcase.

Inspect camshaft (9–Fig. D1-16) and bearings for excessive wear. Cam height for F1L 208 D engine should be 6.85-6.95 mm (0.2697-0.2736 inch) for intake and exhaust. Cam height for F1L 210 D engine should be 6.55-6.65 mm (0.2579-0.2618 inch). Check governor weights (6), plate (5) and disc (4) for wear and damage and renew if necessary.

To reinstall camshaft, reverse the removal procedure. Be sure to align timing gear marks as shown in Fig. D1-11. Check and adjust camshaft end play as outlined in TIMING GEARS AND FRONT COVER section.

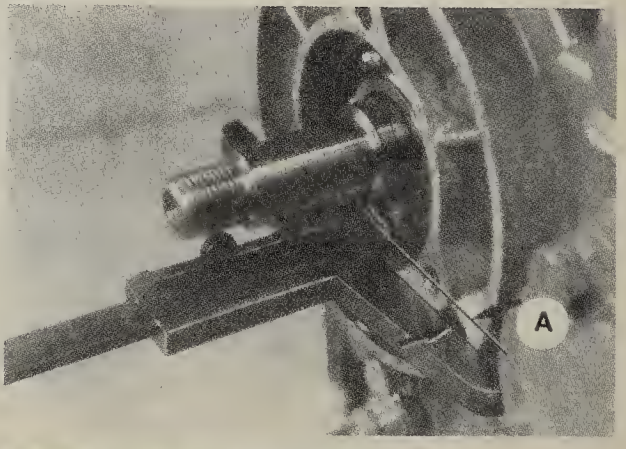


Fig. D1-13—To determine balance weight shaft end play, first measure distance "A" from surface of front cover to race of bearing. Refer to text and Fig. D1-14.

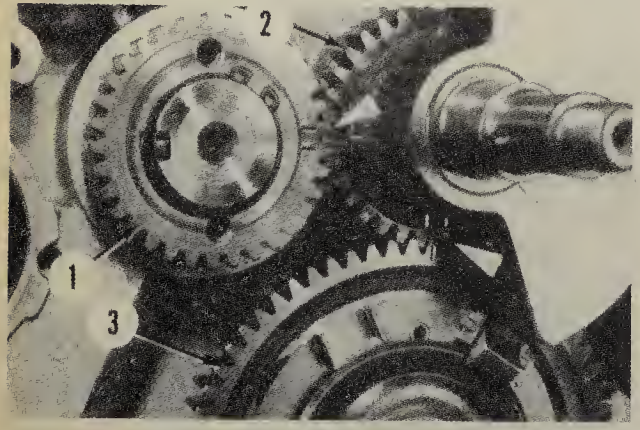


Fig. D1-11—Make certain timing marks are aligned as shown when reassembling engine.

1. Crankshaft gear
2. Balance weight gear
3. Camshaft gear

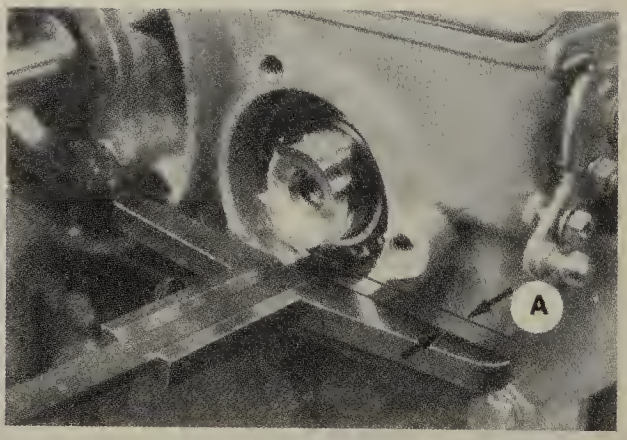


Fig. D1-14—To determine camshaft end play, measure distance "A" from surface of front cover to race of bearing. Refer to text.

Fig. D1-15—Measure bearing retainer flange distance "B" with gasket in place. Refer to text.

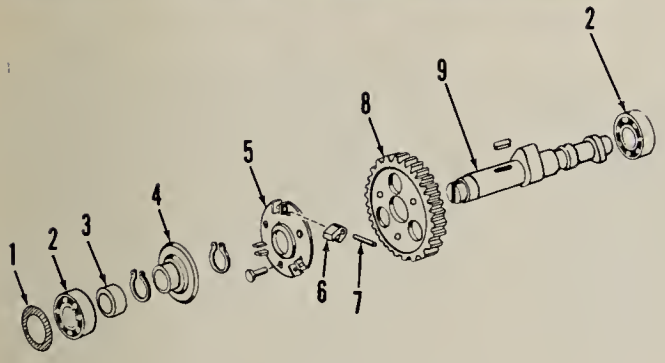


Fig. D1-16—Exploded view of camshaft assembly.
1. Shim
2. Bearings
3. Spacer
4. Governor disc
5. Flyweight plate
6. Flyweight
7. Pivot pin
8. Camshaft gear
9. Camshaft

Ring Side Clearance

F1L 208 D:
Top ring.....0.09-0.11 mm (0.0035-0.0043 inch)
Maximum.....0.15 mm (0.006 inch)
Second ring.....0.05-0.07 mm (0.0020-0.0027 inch)
Maximum.....0.15 mm (0.006 inch)
Slotted oil ring.....0.03-0.05 mm (0.0012-0.0020 inch)
Maximum.....0.15 mm (0.006 inch)

F1L 210 D:
Top ring.....0.11-0.13 mm (0.0044-0.0051 inch)
Maximum.....0.20 mm (0.008 inch)
Second ring.....0.07-0.09 mm (0.0028-0.0035 inch)
Maximum.....0.15 mm (0.006 inch)
Slotted oil ring.....0.03-0.05 mm (0.0012-0.0020 inch)
Maximum.....0.15 mm (0.006 inch)

PISTON, PISTON RING, RINGS AND CYLINDER

To disassemble, remove cylinder head and air shroud. Withdraw cylinder from piston and crankcase. Retain shims used between bottom of cylinder and crankcase for use in reassembly. Remove piston pin retaining rings. Press out piston pin and remove piston from connecting rod.

Cylinder standard bore diameter is 80.00-80.015 mm (3.1496-3.1502 inches) for F1L 208 D and 95.00-95.015 mm (3.7402-3.7407 inches) for F1L 210 D. Cylinder should be renewed if wear exceeds 0.15 mm (0.006 inch). Piston skirt standard diameter should be 79.805-79.825 mm (3.1419-3.1427 inches) for F1L 208 D and 94.780-94.800 mm (3.7315-3.7322 inches) for F1L 210 D. Pistons and cylinders are available in oversizes of 0.50 mm (0.020 inch) and 1.0 mm (0.040 inch).

With rings installed on piston, measure side clearance between rings and ring grooves using a feeler gage. Compare measurements with the following dimensions and renew if necessary.

Piston ring end gap should be checked using a feeler gage with ring inserted squarely into cylinder bore. On F1L 208 D engine, ring end gap should be 0.25-0.50 mm (0.010-0.020 inch) and maximum allowable gap is 1.0 mm (0.040 inch) for all rings. On F1L 210 D engine, ring end gap should be 0.25-0.55 mm (0.010-0.021 inch) and maximum allowable gap is 1.0 mm (0.040 inch) for all rings.

The piston pin is a transition fit in piston bore. Heating piston to about 80°C (175°F) will make removal and installation easier. Piston pin outer diameter is 27.994-28.000 mm (1.1021-1.1023 inches) and piston bore diameter is 28.000-28.006 mm (1.1023-1.1026 inches).

When reassembling, note that combustion cavity is offset in piston crown.

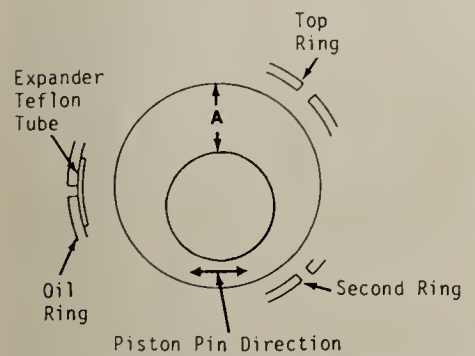


Fig. D1-17—Stagger ring end gaps around piston as shown. Note that combustion cavity in piston crown is offset and wider part of crown (A) should be towards injection pump side of engine.

Fig. D1-18—To check piston crown clearance, secure cylinder using spacers (1) and stud nuts. Measure distance from top of cylinder to piston crown using a depth gage (2).

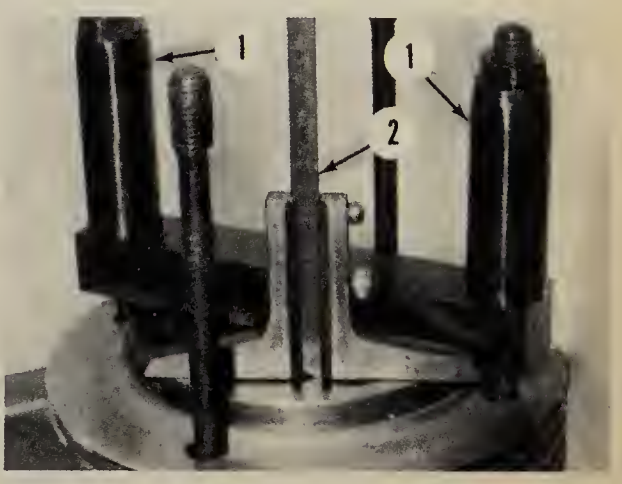


Fig. D1-19—Make certain identification numbers (1) on rod and cap match and are on the same side.

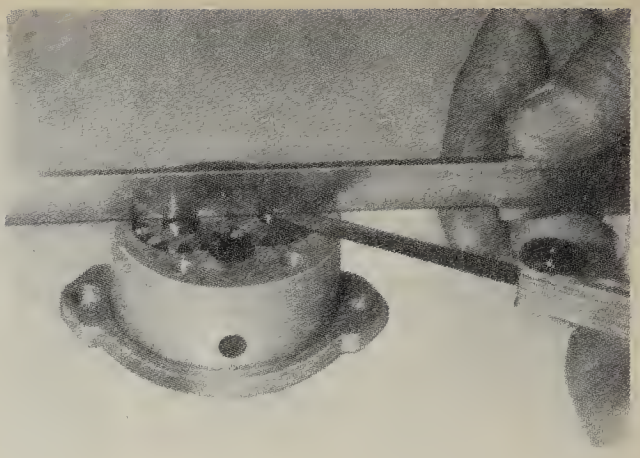


Fig. D1-20—Use a straightedge and feeler gage to measure oil pump end clearance.

Install piston so wider part of piston crown (A—Fig. D1-17) is towards injection pump side of engine. If connecting rod is removed, make certain side of rod and cap stamped with identification numbers (Fig. D1-19) is opposite from wider side of piston crown. Install rings onto piston making sure second compression ring is installed with side marked "TOP" facing upward and chrome plated ring is installed in top ring groove. Stagger ring end gaps around piston as shown in Fig. D1-17. Position cylinder so side with flattened fins is towards camshaft side of crankcase.

If piston or cylinder was renewed, piston crown clearance should be checked and adjusted as follows: Assemble three shims onto bottom of cylinder, then install cylinder onto piston. Using suitable spacer tubes (1—Fig. D1-18) on cylinder studs, tighten stud nuts securely to clamp cylinder against crankcase. Rotate crankshaft until piston is at top dead center, then measure distance between piston crown and top of cylinder. Recommmended distance is 1.0-1.2 mm (0.040-0.047 inch). If measured distance is too large, lift cylinder slightly and cut one of the shims with side cutters. Remove the cut shim and recheck piston crown dimension. When specified dimension is obtained, reinstall cylinder head.

CONNECTING ROD

The connecting rod is equipped with a renewable, precision insert type bearing in the big end. Bearings are available in undersizes of 0.25, 0.50, 0.75 and 1.00 mm (0.010, 0.020, 0.030 and 0.040 inch) as well as standard size. Bearing standard bore diameter is 40.025-40.052 mm (1.5758-1.5768 inches) for F1L 208 D and 51.955-51.994 mm (2.0455-2.0470 inches) for F1L 210 D. Recommended clearance between bearing and crankpin is 0.025-0.068 mm (0.0010-0.0026 inch) for F1L 208 D and 0.010-0.069 mm (0.0004-0.0027 inch) for F1L 210 D. Maximum allowable operating clearance for both engines is 0.12 mm (0.0047 inch).

Inside diameter of small end bore is 28.005-28.015 mm (1.1026-1.1029 inches) for F1L 208 D and outside diameter of piston pin is 27.994-28.000 mm (1.1021-1.1023 inches). Desired clearance of pin in rod bore is 0.005-0.021 mm (0.0002-0.0008 inch) with a wear limit of 0.05 mm (0.0020 inch). Inside diameter of small end bore for F1L 210 D engine is 30.005-30.015 mm (1.1813-1.1817 inches) and outside diameter of piston pin is 29.994-30.000 mm (1.1809-1.1811 inches). Desired clearance of piston pin in rod bore is 0.005-0.021 mm (0.0002-0.0008 inch) with a wear limit of 0.05 mm (0.0020 inch).

Connecting rod side clearance on crankshaft should be 0.20-0.40 mm (0.008-0.016 inch) for all engines. Renew connecting rod if side clearance exceeds 0.60 mm (0.023 inch).

When reinstalling connecting rod, be sure identification numbers (Fig. D1-19) on big end of rod and on cap are on the same side and face away from injection pump side of engine.

NOTE: If connecting rod bearing is renewed, manufacturer recommends renewing connecting rod cap screws.

Tighten connecting rod cap screws to 35 N·m (26 ft.-lbs.) on F1L 208 D engine or 45 N·m (33 ft.-lbs.) on F1L 210 D engine.

CRANKSHAFT AND MAIN BEARINGS

To remove crankshaft, remove cylinder head, oil sump, connecting rod and piston and engine front cover. Remove crankshaft gear and flywheel using suitable pullers. Use two jackscrews in threaded holes of crankshaft rear bearing retainer to pull retainer housing from crankcase. Withdraw crankshaft from crankcase.

Crankpin standard diameter is 39.984-40.000 mm (1.5742-1.5748 inches) for F1L 208 D engine or 51.925-51.945 mm (2.0443-2.0450 inches) for F1L 210 D engine. Journal out-of-round limit is 0.05 mm (0.002 inch). Recommended clearance between connecting rod bearing and crankpin is 0.025-0.068 mm (0.0010-0.0026 inch) for F1L 208 D engine or 0.010-0.069 mm (0.0004-0.0027 inch) for F1L 210 D engine. Maximum allowable clearance for both engines is 0.12 mm (0.0047 inch). Undersize bearings are available.

Main journal standard diameter is 46.995-47.011 mm (1.8502-1.8508 inches) for F1L 208 D engine or 54.993-55.006 mm (2.1651-2.1656 inches) for F1L 210 D engine. Journal out-of-round limit is 0.05 mm (0.002 inch). Standard inside diameter of main bearings is 47.030-47.039 mm (1.8516-1.8519 inches) for F1L 208 D engine or 55.030-55.079 mm (2.1665-2.1684 inches) for F1L 210 D engine. Recommended clearance between main journals and bearings is 0.019-0.084 mm (0.0008-0.0033 inch) for F1L 208 D engine or 0.024-0.086 mm (0.0009-0.0034 inch) for F1L 210 D engine. Maximum allowable main bearing clearance is 0.12 mm (0.0047 inch) for both engines. Undersize bearings are available.

When renewing main bearings, crankcase and bearing retainer should be heated slightly prior to installing new bearings. Press front bearing in until flush with outer surface of crankcase bore and install rear bearing flush with inner surface of retainer housing.

Crankshaft end thrust is taken by thrust washers mounted in crankcase at front and in bearing retainer housing at rear. Recommended end play is 0.15-0.20 mm (0.006-0.008 inch) for both engines. Maximum allowable end play is 0.40 mm (0.016 inch). Standard thickness of thrust washers is 1.95-2.00 mm (0.077-0.079 inch). If end play is excessive, insert a shim behind thrust washers. If end play is less than recom-

Fig. D1-21—Measure clearance between oil pump body and gears with a feeler gage. Refer to text.

mended, assemble thicker mounting gasket for rear bearing retainer.

When reinstalling crankshaft, lubricate bearings and journals with oil prior to assembly. Be sure side of thrust washers with oil grooves is towards crankshaft. Tighten bearing retainer nuts to 35 N·m (26 ft.-lbs.). Be sure timing gear marks are aligned as shown in Fig. D1-11. Complete installation by reversing the removal procedure.

OIL PUMP

To remove oil pump, drain the engine oil and remove oil pan and engine front cover. Remove oil pickup tube. Remove pump mounting screws and withdraw pump assembly from crankcase.

Use a straightedge to check pump rear cover for distortion or wear. Renew cover and pickup assembly if warped or excessively worn. Use a straightedge and feeler gage to measure gear end clearance (Fig. D1-20). Specified end clearance is 0.07-0.15 mm (0.003-0.006 inch). Renew components as required if end clearance exceeds 0.15 mm (0.006 inch). Use a feeler gage to measure clearance between gears and housing as shown in Fig. D1-21. Specified clearance is 0.03-0.10 mm (0.001-0.004 inch) and maximum allowable clearance is 0.15 mm (0.006 inch). Backlash between pump gears should be 0.06-0.12 mm (0.0023-0.0047 inch) with a wear limit of 0.20 mm (0.008 inch).

To reinstall pump, reverse the removal procedure. Tighten pump cover mounting screws to 8.5 N·m (75 in.-lbs.). Be sure pump mounting screw with smaller head (Fig. D1-12) is installed in outer hole. Rotate pump in crankcase to obtain recommended backlash of 0.10-0.15 mm (0.004-0.006 inch) between pump drive gear and crankshaft gear. Tighten pump mounting screws to 10 N·m (88 in.-lbs.).

Engine oil pressure with oil at 80°C (175°F) and engine running at 3200 rpm should be 300-500 kPa (44-72 psi).

FARYMANN

BRIGGS & STRATTON CORP.
Milwaukee, Wisconsin 53201

Model	No. Cyls.	Bore	Stroke	Displ.
15A430	1	75 mm (2.953 in.)	55 mm (2.165 in.)	243 cc (14.8 cu. in.)
18A-430	1	82 mm (3.228 in.)	55 mm (2.165 in.)	290 cc (17.7 cu. in.)

Engines covered in this section are single cylinder, air-cooled, diesel engines. Crankshaft rotation is counterclockwise at flywheel end of engine.

Metric fasteners are used throughout engine.

MAINTENANCE

LUBRICATION

Recommended engine oil is SAE 10W for temperatures below 0°C (32°F), SAE 20W-20 for temperatures between 0°C (32°F) and 30°C (86°F), and SAE 30 for temperatures above 30°C (86°F). API classification for oil should be CD. Fill oil sump to full level on dipstick. Manufacturer recommends renewing oil after first 20 hours of operation and after every 100 hours thereafter.

Both models are equipped with an oil pump to provide pressurized oil for lubrication. The oil pickup (2–Fig. F1-1) may be removed from the gear cover for periodic cleaning and inspection.

ENGINE SPEED ADJUSTMENT

Low idle speed is determined by detents in the speed control lever and is not adjustable. Maximum governed speed is determined by engine application.

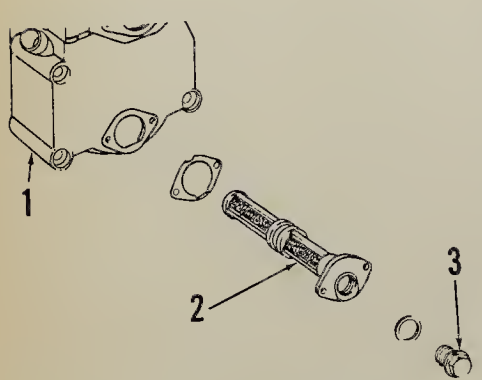


Fig. F1-1—Oil pickup and screen (2) is removable from front cover (1). Oil drain plug (3) screws into pickup mounting flange.

FUEL SYSTEM

FUEL FILTER. A renewable fuel filter is located in the fuel tank. Renew filter after every 50 hours of operation or sooner if required.

BLEED FUEL SYSTEM. Due to gravity feed type of fuel system, air should be bled from system as fuel injection pump operates. However, bleeding time may be shortened by loosening then retightening fuel line fittings, starting first at fuel tank and working to fuel injection pump. Retighten fitting when air-free fuel flows.

INJECTION PUMP TIMING

Injection pump timing is adjusted using shim gaskets (G–Fig. F1-2) between pump body and mounting surface on crankcase. To check injection timing proceed as follows: Disconnect high pressure line from injection pump, then unscrew delivery valve holder (1) and remove spring (6), shim (5), spring guide (4) and delivery valve (7); do not remove valve seat. Reinstall delivery valve holder (1) and connect a suitable spill pipe to valve holder. Aim spill pipe at a receptacle to catch discharged fuel. Move throttle control to full open position. Rotate engine flywheel slowly in counterclockwise direction until fuel just stops flowing from spill pipe. Measure distance from reference mark on flywheel housing to top dead center mark on flywheel. Measured distance should be 18 mm (0.708 inch) if maximum governed rpm is 2000 rpm or less, 21 mm (0.827 inch) if maximum governed rpm is between 2000 rpm and 3300 rpm, or 27 mm (1.063 inches) if maximum governed rpm is 3300 rpm or more. Measured distance should be within plus or minus 2 mm (0.079 inch) of desired distance.

If injection timing is incorrect, remove injection pump and remove or install shims (G–Fig. F1-2) as required. Adding shims will retard injection timing while removing shims advances injection timing. Be sure to reinstall removed pump parts after checking timing. Tighten delivery valve holder to 34-39 N·m (25-29 ft.-lbs.)

REPAIRS

TIGHTENING TORQUES

Refer to the following table for special tightening torques.

Connecting rod	30 N·m (22 ft.-lbs.)
Cylinder head	30 N·m (22 ft.lbs.)
Injection pump	30 N·m (22 ft.-lbs.)
Injector retainer plate	6 N·m (50 in.-lbs.)
Main bearing support	30 N·m (22 ft.-lbs.)
Rocker arm cover	9 N·m (80 in.-lbs.)

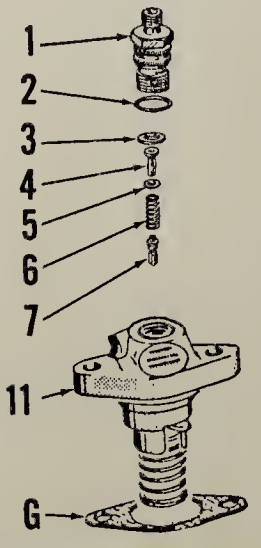


Fig. F1-2—Partial exploded view of fuel injection pump. Injection timing is adjusted using shim gaskets (G).

1. Delivery valve holder
2. "O" ring
3. Gasket
4. Spring guide
5. Shim
6. Spring
7. Delivery valve
11. Fuel injection pump

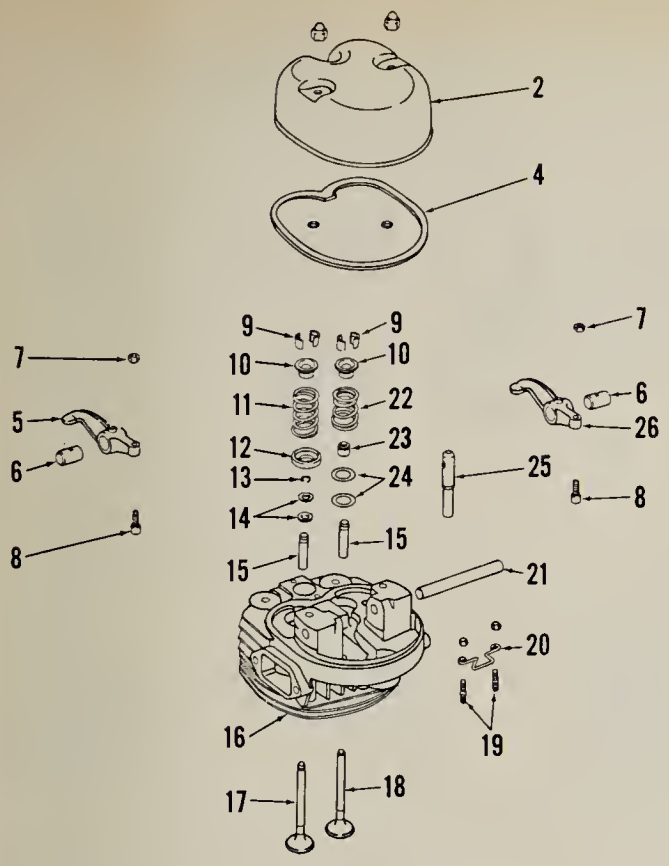


Fig. F1-3—Exploded view of cylinder head.

2. Rocker arm cover
4. Gasket
5. Exhaust rocker arm
6. Bushing
7. Locknut
8. Adjuster
9. Valve keys
10. Retainer
11. Exhaust valve spring
12. Valve rotator
13. Retaining ring
14. Washers
15. Valve guide
16. Cylinder head
17. Exhaust valve
18. Intake valve
19. Studs
20. Push rod tube retainer
21. Rocker arm shaft
22. Intake valve spring
23. Valve seal
24. Washers
25. Breather
26. Intake rocker arm

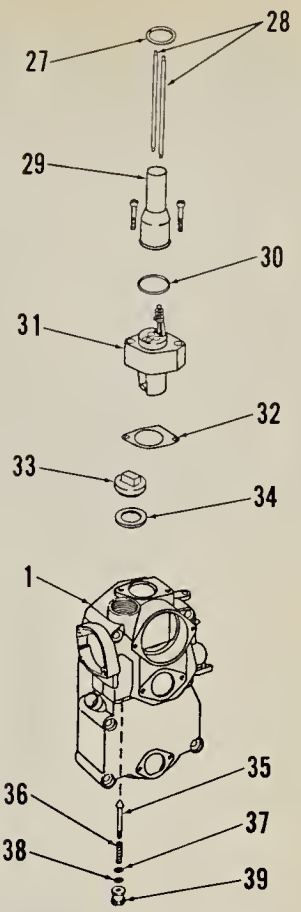


Fig. F1-4—Exploded view of push rod tube and excess fuel assemblies. Excess fuel components (35 through 39) are not used on Model 15A430.

1. Front cover
27. "O" ring
28. Push rods
29. Push rod tube
30. "O" ring
31. Tappet housing & compression release
32. Gasket
33. Oil fill plug
34. Gasket
35. Excess fuel shaft
36. Spring
37. Washer
38. "O" ring
39. Knob

VALVE CLEARANCE

Valve clearance may be adjusted after removing rocker arm cover. Piston should be at top dead center on compression stroke and compression release must be in "OFF" position. Turn adjuster screw (8–Fig. F1-3) until clearance between rocker arm and valve stem end is 0.1 mm (0.004 inch) for both valves with engine cold.

COMPRESSION RELEASE

Compression release (31–Fig. F1-4) is manually operated to raise the intake valve to aid engine starting. Compression release is not adjustable. Install a new "O" ring (30) on push rod tube when reassembling.

CYLINDER HEAD AND VALVE SYSTEM

Valve face and valve seat angles are 45 degrees for intake and exhaust valves. Minimum allowable depth of valve in head measured from top of valve to cylinder head surface is 0.0-0.1 mm (0-0.004 inch). Valve guides (15–Fig. F1-3) are renewable and identical. Valve springs are dissimilar. Note that rotator (12) is located under the exhaust valve spring and valve stem seal (23) is used on the intake valve.

Install a new "O" ring (27–Fig. F1-4) around push rod tube before installing cylinder head. Model 18A430 is equipped with a head gasket while Model 15A430 is not so equipped. Tighten cylinder head retaining nuts in a crossing pattern to a torque of 30 N·m (22 ft.-lbs.). Install clip (20–Fig. F1-3) so clip bears against end of push rod tube. Push rod nearer cylinder is connected to intake valve rocker arm.

INJECTOR

REMOVE AND REINSTALL. To remove injector, first clean dirt from injector, injection line, return line and cylinder head. Disconnect return line and high pressure injection line and immediately cap or plug all openings. Unscrew retainer plate and remove injector and asbestos washer.

Reverse removal procedure to reinstall injector. Install a new asbestos washer (8–Fig. F1-5). Tighten injector retainer plate nuts to 6 N·m (50 in.-lbs.).

TESTING. WARNING: Fuel leaves the injection nozzle wiht sufficient force to penetrate the skin. When testing, keep yourself clear of nozzle spray.

If a suitable test stand is available, injector, operation may be checked. Only clean, approved testing oil should be used to test injector. When operating properly during test, injector nozzle will emit a buzzing sound and cut off quickly with no fluid leakage at seat.

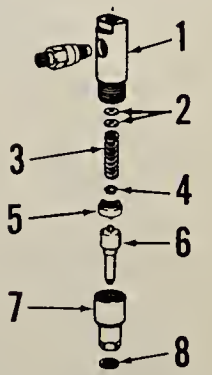


Fig. F1-5—Exploded view of injector.

1. Injector body
2. Shims
3. Spring
4. Push piece
5. Spacer
6. Nozzle & valve
7. Nozzle holder nut
8. Asbestos washer

Opening pressure should be 20270 kPa (2940 psi). Opening pressure is adjusted by varying thickness of shims (2–Fig. F1-5).

OVERHAUL. Clamp injector body (1–Fig. F1-5) in a vise with nozzle pointing upward, unscrew nozzle holder nut (7), then remove injector components shown in Fig. F1-5. Thoroughly clean all

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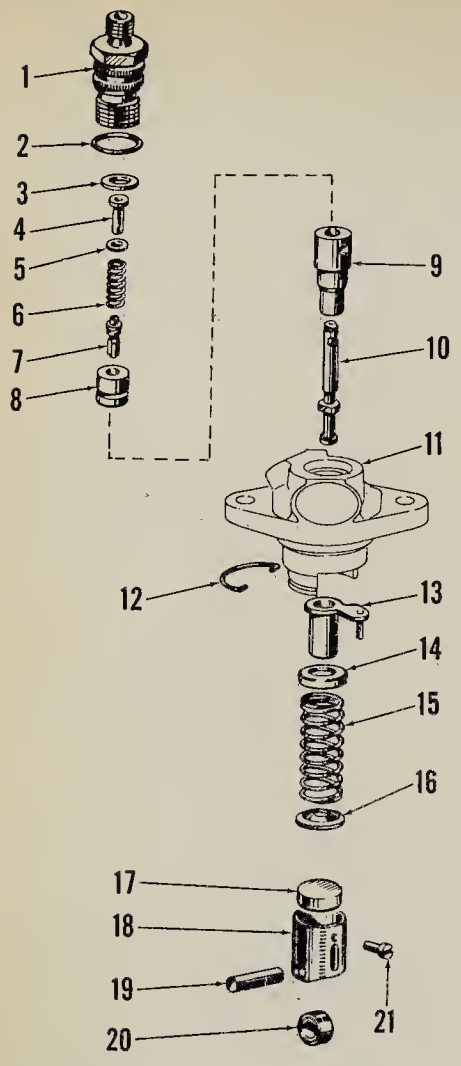

Fig. F1-6—Exploded view of fuel injection pump.

1. Delivery valve holder
2. "O" ring
3. Gasket
4. Spring guide
5. Shim
6. Spring
7. Delivery valve
8. Delivery valve seat
9. Barrel
10. Plunger
11. Body
12. Clip
13. Control sleeve
14. Spring seat
15. Spring
16. Spring retainer
17. Spacer
18. Tappet
19. Pin
20. Roller
21. Pin

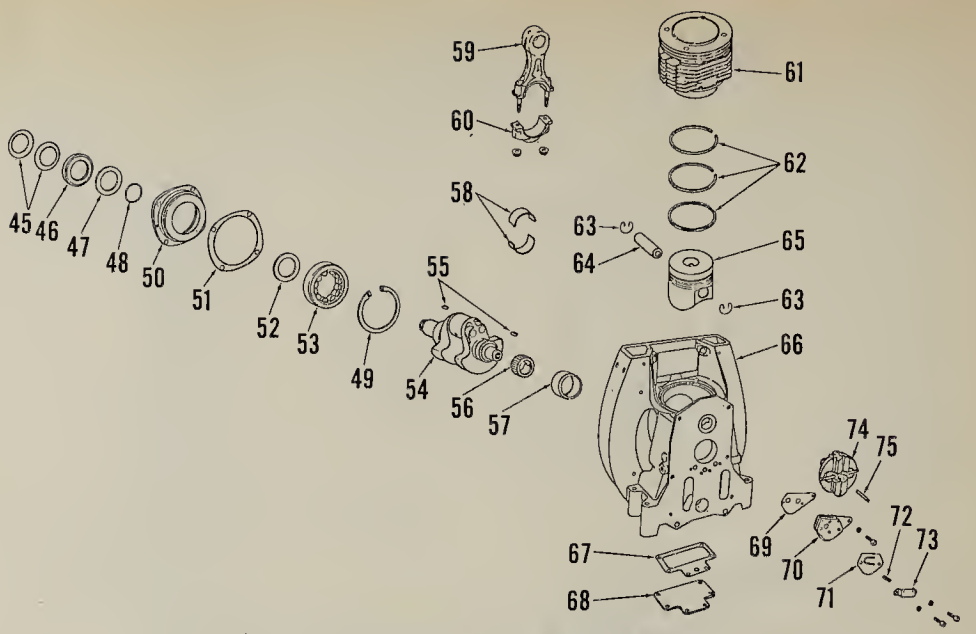

Fig. F1-7—Exploded view of crankcase assembly.

45. Belleville washers
46. Seal
47. "O" ring retainer
48. "O" ring
49. Snap ring
50. Main bearing support
51. Gasket
52. Washer
53. Bearing
54. Crankshaft
55. Keys
56. Gear
57. Bushing
58. Rod bearing
59. Connecting rod
60. Rod cap
61. Cylinder
62. Piston rings
63. Piston pin retainer
64. Piston pin
65. Piston
66. Crankcase
67. Gasket
68. Cover
69. Gasket
70. Oil pump
71. Relief valve plate
72. Relief valve spring
73. Spring retainer
74. Governor flyweight assy.
75. Pin

parts in a suitable solvent. Clean inside orifice of nozzle tip with a wooden cleaning stick. When reassembling injector, make certain all components are clean and wet with clean diesel fuel oil. Tighten nozzle holder nut (7) to 24-29 N·m (18-22 ft.-lbs.).

INJECTION PUMP

R&R AND OVERHAUL. To remove fuel injection pump, disconnect fuel lines and immediately cap or plug all openings. Unscrew pump retaining nuts and remove fuel injection pump. Do not lose shim gaskets (G – Fig. F1-2). Pump components (17 through 21 – Fig. F1-6) will remain in crankcase, and timing gear cover must be removed for access.

Refer to Fig. F1-6 for an exploded view of fuel injection pump. The injection pump should be tested and overhauled by a shop qualified in diesel fuel injection pump repair.

Model 18A430 is equipped with an excess of fuel device (35 through 39 – Fig. F1-4) to aid starting. Pushing up on starter knob (39) forces shaft (35) against governor arm which moves fuel injection pump control arm to intermediate position for additional fuel.

Reverse removal procedure to reinstall pump. Tighten pump mounting nuts to 30 N·m (22 ft.-lbs.) If pump is renewed or overhauled, or original shim gaskets are not used, refer to INJECTION PUMP TIMING section and adjust pump timing.

CYLINDER, PISTON, PIN AND RINGS

R&R AND OVERHAUL. The cylinder is removable after removing cylinder head. After cylinder is removed, cover crankcase opening to prevent entry of foreign material. Extract piston pin retainers (63 – Fig. F1-7), remove piston pin, then separate piston from connecting rod.

Nominal standard cylinder bore diameter measured at top of cylinder is 74.86-74.88 mm (2.947-2.948 inches) on Model 15A430 governed at 1800 rpm or less, and 74.91-74.93 mm (2.949-2.950 inches) on Model 15A430 governed at engine speeds above 1800 rpm. Nominal standard cylinder bore diameter measured at top of cylinder is 81.88-81.90 mm (3.2236-3.2244 inches) on Model 18A430 governed at 1800 rpm or less, and 81.94-81.96 mm (3.226-3.227 inches) on Model 18A430 governed at engine speeds above 1800 rpm. Cylinder and piston are available in standard size only.

Piston ring end gap should be 0.2-0.8 mm (0.008-0.031 inch) with piston ring located 25 mm (1 inch) from top of cylinder.

Reverse removal procedure for installation. With cylinder installed and held against crankcase, measure height of piston from top edge of cylinder. Piston on Model 15A430 should be beneath top of cylinder a distance of

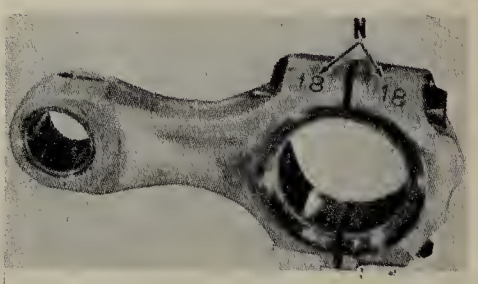

Fig. F1-8—View of connecting rod and cap showing location of stamped numbers (N) which must be on same side after assembly.

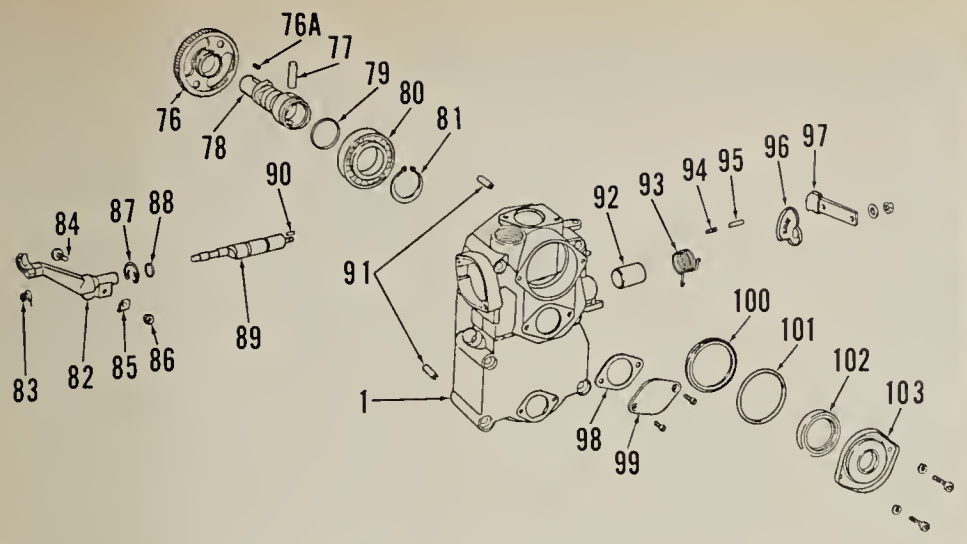

Fig. F1-9—Exploded view of front cover assembly.

1. Front cover
76. Gear
76A. Key
77. Starter pin
78. Camshaft
79. "O" ring
80. Bearing
81. Snap ring
82. Governor arm
83. Spring
84. Flat-head screw
85. Lockwasher
86. Locknut
87. Retaining ring
88. "O" ring
89. Shaft
90. Pin
91. Dowel pins
92. Bushing
93. Spring
94. Spring
95. Detent pin
96. Detent plate
97. Speed control lever
98. Gasket
99. Cover
100. "O" ring retainer
101. "O" ring
102. Seal
103. Starter guide

0.475-0.800 mm (0.019-0.031 inch). Piston height above top edge of cylinder on Model 18A430 should be 0.650-0.975 mm (0.026-0.038 inch). Note that Model 15A430 is not equipped with a cylinder head gasket while Model 18A430 is so equipped.

CONNECTING ROD

REMOVE AND REINSTALL. To remove connecting rod, drain oil and remove cylinder. Detach cover (68—Fig. F1-7) on crankcase bottom. Reach through cover opening, unscrew rod cap retaining nuts and withdraw rod cap through cover opening. Remove piston and rod unit from top of engine. If required, separate piston from rod.

An insert type bearing is used in connecting rod big end while a non-renewable bushing is located in rod small end. Standard crankpin diameter is 40.020-40.030 mm (1.5756-1.5760 inches.) Big end bearing clearance of both models should be 0.03-0.05 mm (0.0012-0.0019 inch). Connecting rod big end bearing is available in standard size and undersizes of 0.25 and 0.50 mm.

Reverse removal procedure to install connecting rod while noting the following: The connecting rod side with a paint mark should be towards the fuel injection pump. Install rod cap so stamped numbers (N—Fig. F1-8) on rod and cap are on same side. Tighten connecting rod nuts to 30 N·m (22 ft.-lbs.).

FRONT COVER

REMOVE AND REINSTALL. To remove front cover (1—Fig. F1-9), drain oil, then remove rocker arm cover and extract push rods. Remove push rod tube hold down clip (20—Fig. F1-3) and slide push rod tube up into cylinder head. Remove fuel injection pump. Unscrew six front cover screws and remove front cover; it may be necessary to rotate engine crankshaft if governor mechanism snags.

Fig. F1-12—Align flywheel mark (M) with threaded hole (H) when using alternate front cover installation method outlined in text.

When reinstalling front cover, camshaft and crankshaft gears must be correctly timed using the following procedure: Rotate crankshaft so top dead center mark on flywheel is aligned with reference mark on crankcase as shown in Fig. F1-10. Rotate camshaft gear so gear mark is aligned with mark in tappet housing bore of front cover as shown in Fig. F1-11. Install gasket and front cover on crankcase being careful not disturb camshaft gear (three long screws are located in top two holes and bottom left hole). After tightening front cover screws, recheck timing marks (M—Fig. F1-10 and T—Fig F1-11). Gear timing is correct if marks (M—Fig. F1-10) are within 6.35 mm (¼ inch) of

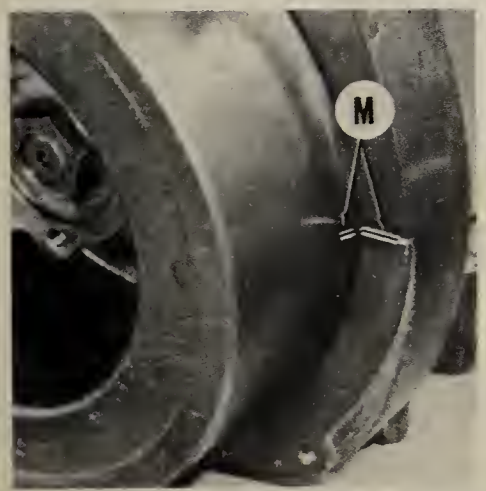

Fig. F1-10—Piston is at top dead center when marks (M) on flywheel and crankcase are aligned.

Fig. F1-11—View of timing marks (T) on camshaft gear and tappet housing opening in front cover.

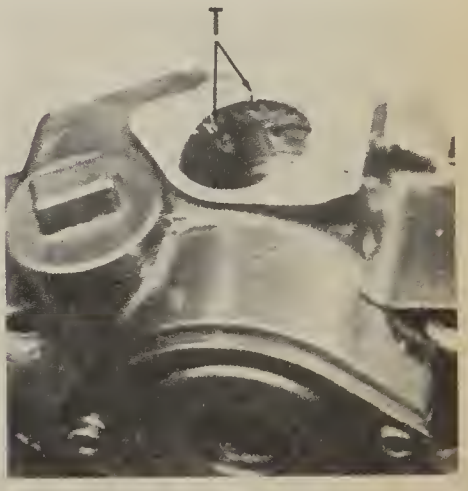

Fig. F1-13—Position camshaft gear so timing marks (T) on gear and tappet housing opening are three teeth apart as shown. Refer to text.

alignment when marks (T – Fig. F1-11) are aligned.

NOTE: Do not attempt to force front cover into place. Interference of governor mechanism may prevent front cover from mating with crankcase. Use procedure in following paragraph to install front cover.

If front cover cannot be installed using preceding procedure, use the following procedure: Rotate engine crankshaft so flywheel top dead center mark (M – Fig. F1-12) is aligned with threaded hole (H) in crankcase. Position camshaft gear so gear mark is three teeth to left of timing mark in tappet housing bore in cover as shown in Fig. F1-13. Install gasket and front cover on crankcase being careful not ot disturb camshaft gear (three long screws are located in top two holes and bottom left hole). After tightening front cover screws, recheck timing marks. Gear timing is correct if marks (M – Fig. F1-10) are within 6.35 mm (¼ inch) of alignment when marks (T – Fig. F1-11) are aligned.

Complete remainder of assembly by reversing disassembly procedure.

OIL PUMP

R&R AND OVERHAUL. Remove the front cover as previously outlined for access to the oil pump. Remove oil pump components (69 through 73 – Fig. F1-7). Be careful when handling oil pressure relief valve plate (71) and spring (72) as oil pressure may be affected. Oil pump (70) is available only as a unit assembly. Install oil pump by reversing removal procedure. Do not overtighten oil pump screws

Oil pressure may be measured by removing plug in injection pump side of crankcase and connecting a suitable gage to plug hole. Oil pressure with engine at normal operating temperature should be at least 80 kPa (12 psi) at low idle speed and no more than 400 kPa (58 psi) at maximum engine speed. Oil pressure is not adjustable.

GOVERNOR

R&R AND OVERHAUL. Remove front cover as previously outlined for access to governor. Governor shaft assembly may be disassembled after detaching retaining ring (87 – Fig. F1-9). Remove pin (75 – Fig. F1-7) and unscrew governor flyweight assembly (74) from crankshaft; **note that stud has left-hand threads.**

Governor flyweight assembly (74) is available as a unit assembly. Flyweight springs are available, however, be sure correct governor flyweight assembly or springs are installed so engine will operate at rpm stamped on engine identification plate.

Reassemble governor as follows: Install flyweight assembly (74) on crankshaft and tighten to 34 N·m (25 ft.-lbs.); **note that stud has left-hand threads.** Install flathead screw (84 – Fig. F1-9), lockwasher (85) and nut (86) so flat head is opposite governor arm. Place governor arm (82) in front cover. Install pin (90), spring (93), plate (96), lever (97) and "O" ring (88) on shaft plate (89). Insert shaft assembly into front cover and governor arm (82). Turn lever (97) so it points toward bottom of front cover (away from camshaft), then install spring (83) so small spring end engages slot in shaft end and long spring end is on same side as nut (86). Install retaining ring (87), then engage long end of spring (93) with boss on side of front cover. Engage short end of spring (93) in middle notch of plate (96) then install retaining ring (87) in shaft groove. Engage long end of spring (93) with pin on side of front cover. Note that spring (93) should return lever (97) from stop position to idle position and it may be necessary to relocate short spring end in another notch to increase spring tension. Install front cover as previously outlined.

With front cover installed, adjust position of flat-head screw (84) as follows: Remove cover (99) then rotate crankshaft so governor flyweights are positioned with mating surfaces vertical. Loosen locknut (86). Using a small screwdriver, spread flyweights apart as far as they will go. Turn screw (84) so it just contacts pin (75 – Fig. F1-7), release flyweights, then turn screw (84 – Fig. F1-9) in an additional ½ turn. Without disturbing screw, tighten locknut.

CAMSHAFT AND TAPPETS

R&R AND OVERHAUL. To remove camshaft, remove front cover as out lined in FRONT COVER section. Remove tappet and compression release housing (31 – Fig. F1-4) and components (100 through 103 – Fig. F1-9). Remove snap ring (81) and press camshaft (78) out of bearing (80). Then, press bearing (80) out of front cover (1).

Inspect cam lobes and bearing journals and renew camshaft if excessively worn or damaged. Inspect tappets and tappet housing bores. The manual starter handle is supported by guide (103) and starter end engages pin (77) in camshaft end. Inspect guide (103), pin (77) and camshaft end for damage.

Reverse removal procedure for installation. It is necessary to twist rather than drive guide (103) into position in front cover. Install front cover as outlined in FRONT COVER section to properly time camshaft and crankshaft gears.

CRANKSHAFT AND CRANKCASE

R&R AND OVERHAUL. To remove crankshaft, drain oil and remove flywheel, front cover and connecting rod. Remove governor flyweight assembly (74 – Fig. F1-7) from crankshaft. Remove Belleville washers (45), washers (47 and 52) and "O" ring (48). Unscrew main bearing support nuts and remove main bearing support (50). If main bearing support will not remove easily, jack screws may be threaded into holes provided in support to push support free from crankcase. Remove crankshaft.

The governor end of crankshaft is supported by bushing (57). Standard crankshaft journal diameter at governor end should be 40.020-40.030 mm (1.5756-1.5760 inches). Clearance between crankshaft journal and bushing should be 0.04-0.06 mm (0.0016-0.0023 inch). Bushing (57) is available in standard size and undersizes of 0.25 and 0.50 mm.

Reverse removal procedure to install crankshaft while noting the following: Tighten main bearing support nuts to 30 N·m (22 ft.-lbs.). Install "O" ring retainer (47) with beveled face towards "O" ring. Install Belleville washers (45) with concave faces towards each other.

FARYMANN

Model	No. Cyls.	Bore	Stroke	Displ.
25A430	1	80 mm (3.150 in.)	82 mm (3.228 in.)	412 cc (25.1 cu. in.)
36A430	1	95 mm (3.740 in.)	82 mm (3.228 in.)	581 cc (35.5 cu. in.)
36E435	1	95 mm (3.740 in.)	82 mm (3.228 in.)	581 cc (35.5 cu. in.)
71A437	2	95 mm (3.740 in.)	82 mm (3.228 in.)	1162 cc (45.7 cu. in.)
95A437	2	105 mm (4.134 in.)	90 mm (3.543 in.)	1558 cc (95.1 cu. in.)

Engines covered in this section are four-stroke, air-cooled diesel engines. Crankshaft rotation is counterclockwise at flywheel end of engine. Number 1 cylinder on two-cylinder models is nearer flywheel.

Metric fasteners are used throughout engine.

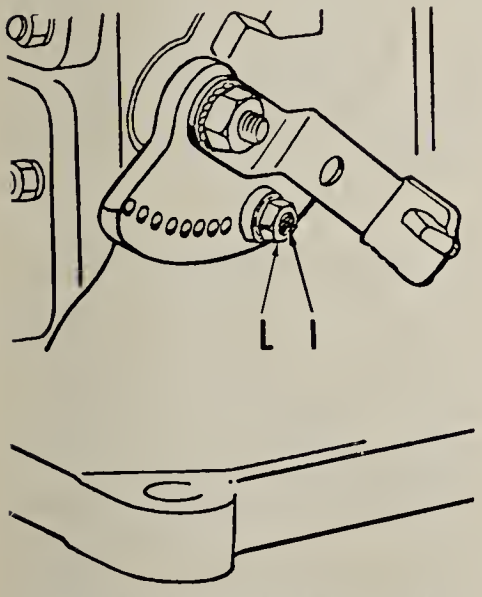

Fig. F2-1—Adjust low idle speed by loosening locknut (L), then turn screw (I) so detent can be relocated in plate.

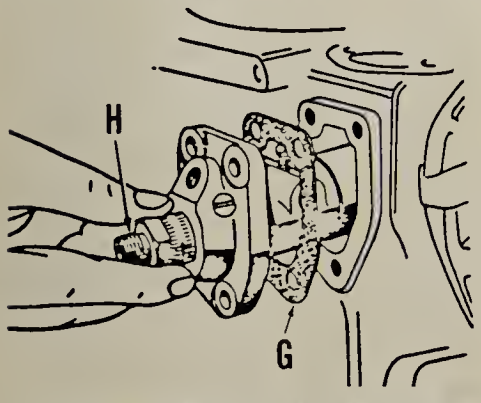

Fig. F2-2—View showing fuel injection pump timing shim gaskets (G) and delivery valve holder (H).

MAINTENANCE

LUBRICATION

Recommended engine oil is SAE 10W for temperatures below 0°(32°F), SAE 20W-20 for temperatures between 0°C (32°F) and 30°C (86°F), and SAE 30 for temperatures above 30°C (86°F). API classification for oil should be CD. Fill oil sump to full level on dipstick. Manufacturer recommends renewing oil after first 20 hours of operation and after every 100 hours thereafter.

ENGINE SPEED ADJUSTMENT

Low idle speed may be adjusted by loosening locknut (L–Fig. F2-1) and turning screw (I) so detent can be relocated in plate. Maximum governed speed is determined by governor and engine application.

FUEL SYSTEM

FUEL FILTER. A renewable fuel filter is located in the fuel tank. Renew filter after every 500 hours of operation or sooner if required.

BLEED FUEL SYSTEM. To bleed fuel system, loosen fuel line fitting at fuel injection pump or bleed screw on pump, if so equipped. On gravity flow systems, open fuel valve until air-free fuel flows at pump then tighten fuel line fitting or bleed screw. On engines equipped with a fuel transfer pump, open fuel valve and operate pump primer lever until air-free fuel flows at pump then tighten fuel line fitting or bleed screw. On all engines, loosen high pressure injection line at injector then rotate engine crankshaft to operate fuel injection pump until fuel is discharged from injection line. Retighten injection line.

INJECTION PUMP TIMING

Injection pump timing is adjusted using shim gaskets (G–Fig. F2-2) between pump body and mounting surface on crankcase. To check injection timing proceed as follows: Disconnect high pressure line for number 1 cylinder from injection pump, then unscrew delivery valve holder (H) and remove spring and delivery valve; do not remove valve seat. Reinstall delivery valve holder (H) and connect a suitable spill pipe to valve

MODEL	MAXIMUM GOVERNED RPM					
	1500	1800	2000	2500	2800	3000
25A430	15mm (0.590in.)	20mm (0.787in.)	25mm (0.984in.)	30mm (1.181in.)	35mm (1.378in.)	40mm (1.575in.)
36A430	10mm (0.394in.)	15mm (0.590in.)	22mm (0.866in.)	30mm (1.181in.)	33mm (1.299in.)	37mm (1.457in.)
36E435	10mm (0.394in.)	14mm (0.551in.)	20mm (0.787in.)	25mm (0.984in.)	27mm (1.063in.)	30mm (1.181in.)
71A437	21mm (0.827in.)	21mm (0.827in.)	23mm (0.905in.)	27mm (1.063in.)	—	—
95A437	25mm (0.984in.)	29mm (1.142in.)	31mm (1.220in.)	38mm (1.496in.)	—	—

Fig. F2-3—Table listing distance between reference mark on flywheel housing and TDC mark on flywheel used when checking injection timing. Refer to text.

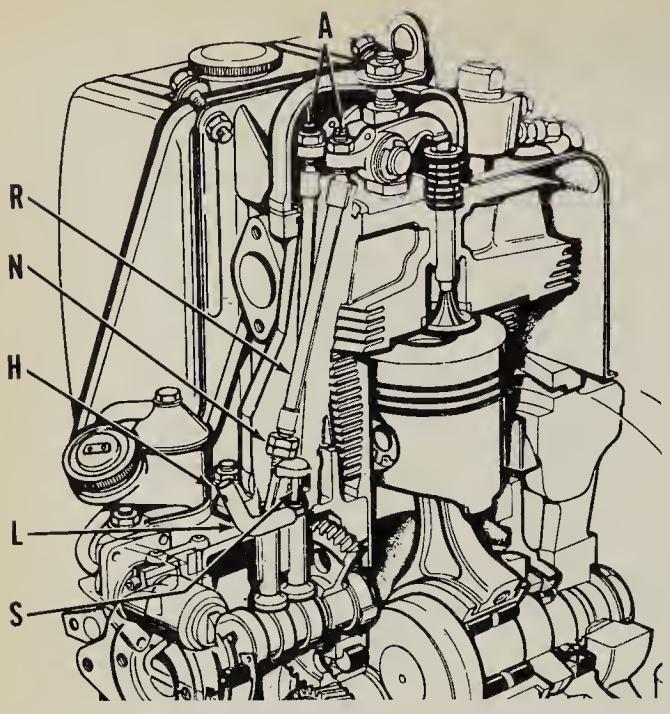

Fig. F2-4—View of valve train for single-cylinder models showing compression release adjustment point. Refer to Fig. F2-6 for twin cylinder models.

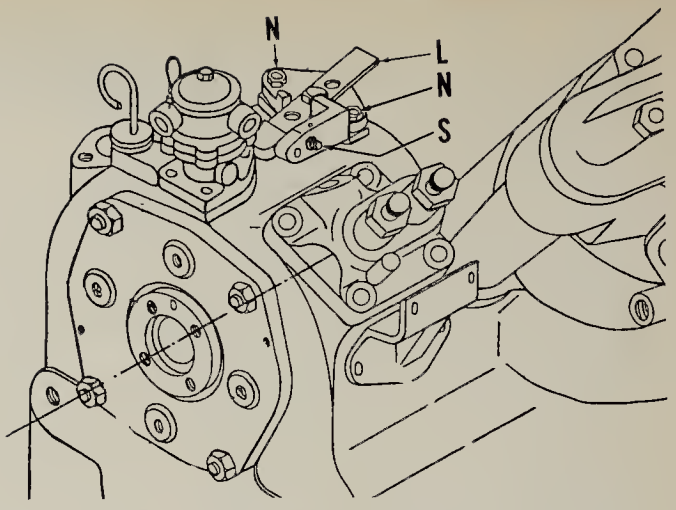

Fig. F2-6—View showing location of compression release on twin-cylinder models.

holder. Aim spill pipe at a receptacle to catch discharged fuel. Move throttle control to full open position. Rotate engine flywheel slowly in counterclockwise direction until fuel just stops flowing from spill pipe. Measure distance from reference mark on flywheel housing to top dead center mark on flywheel. Refer to Fig. F2-3 for desired measured distance for correct injection timing. Measured distance should be within plus or minus 2 mm (0.079 inch) of distance listed in Fig. F2-3.

If injection timing is incorrect, remove injection pump and remove or install shims (G–Fig. F2-2) as required. Adding shims will retard injection timing while removing shims advances injection timing. Be sure to reinstall delivery valve and spring into pump. Tighten delivery valve holder to 34-39 N·m (25-29 ft.-lbs.)

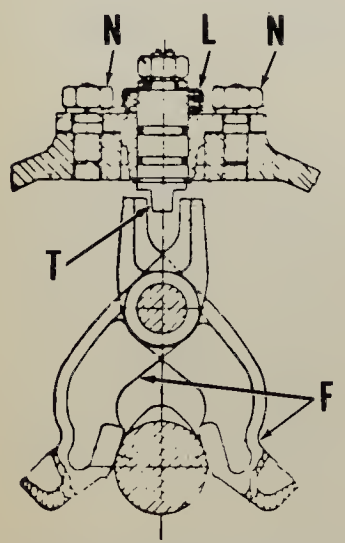

Fig. F2-5—Cross-sectional view of compression release on twin-cylinder models.

REPAIRS

TIGHTENING TORQUES

Refer to the following table for special tightening torques.

Connecting rod:	
95A437	80 N·m (60 ft.-lbs.)
All other models	65 N·m (48 ft.-lbs.)
Cylinder head:	
25A430	45 N·m (33 ft.-lbs.)
36A430, 36E435	54 N·m (40 ft.-lbs.)
71A437	58 N·m (43 ft.-lbs.)
95A437	65 N·m (48 ft.-lbs.)
Injection pump:	
25A430, 71A437	19 N·m (14 ft.-lbs.)
All other models	28 N·m (20 ft.-lbs.)
Injector retainer plate	30 N·m (22 ft.-lbs.)
Main bearing support	30 N·m (22 ft.-lbs.)
Rocker arm bracket	80 N·m (60 ft.-lbs.)
Rocker arm cover	10 N·m (90 ft.-lbs.)

VALVE CLEARANCE

Valve clearance may be adjusted after removing rocker arm cover. Piston should be at top dead center on compression stroke and compression release must be in "OFF" position. Turn adjusting screws (A–Fig. F2-4) until clearance between rocker arm and valve stem end is 0.1 mm (0.004 inch) for both valves with engine cold.

COMPRESSION RELEASE

On single-cylinder models, the intake valve is held open by rotating compression release lever (L–Fig. F2-4) located in valve tappet housing (H). The compression release lever forces spindle (S) against nuts (N) on intake push rod (R) thereby opening the intake valve. The intake valve should open 1.0 mm (0.040 inch) when actuated by compression release lever. Remove rocker arm shaft, extract intake push rod and turn push rod nuts (N) to adjust intake valve opening.

When the compression release lever (L–Fig. F2-5 and F2-6) on twin-cylinder models is turned, tangs (T–Fig. F2-5) on spindle force cam followers (F) to open exhaust valves on Model 71A437 or intake valves on Model 95A437. To adjust compression release, loosen nuts (N–Fig. F2-5 and F2-6), then move lever (L) until resistance is felt indicating spindle tangs are contacting cam followers. Retighten nuts (N). Turn adjusting screw (S–Fig. F2-6) so exhaust valves on Model 71A437 or intake valves on Model 95A437 are opened 1.0 mm (0.040 inch) when compression release lever is operated.

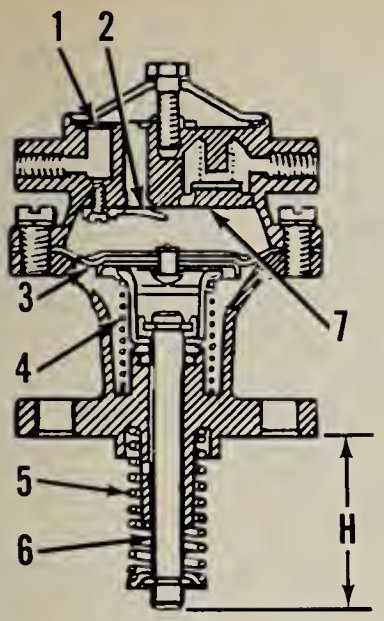

Fig. F2-7—Cross-sectional view of fuel transfer pump. Measure plunger height (H) as outlined in text.

1. Screen
2. Inlet valve
3. Diaphragm
4. Spring
5. Spring
6. Plunger
7. Exhaust valve

CYLINDER HEAD AND VALVE SYSTEM

Cylinder heads and valve components are identical on twin-cylinder engines, however, do not interchange components when servicing engines.

Valve face and valve seat angles are 45° for intake and exhaust valves. Minimum allowable depth of valve in head, measured from top of valve to cylinder head surface, on Model 25A430 is 1.1-1.2 mm (0.043-0.047 inch) for intake valve and 0.4-0.5 mm (0.016-0.020 inch) for exhaust valve. Minimum allowable valve depth on Models 36A430 and 36E435 is 1.1 mm (0.043 inch) for intake valve and 1.4 mm (0.055 inch) for exhaust valve. Minimum allowable valve depth on Models 71A437 and 95A437 is 1.0-1.1 mm (0.040-0.043 inch) for all valves. Valve seats are renewable and must be installed with head heated to 80°-90°C (176°-194°F).

Install a new "O" ring around push rod tube before installing cylinder head. Tighten cylinder head retaining nuts in a crossing pattern starting on injector side of head. Tighten nuts to torque listed in TIGHTENING TORQUES section. Push rod nearer cylinder is connected to exhaust valve rocker arm on single-cylinder models or to intake valve rocker arm on twin-cylinder models.

FUEL TRANSFER PUMP

REMOVE AND REINSTALL. Clean area around fuel pump then disconnect fuel lines. Immediately cap or plug all openings to prevent contamination. Remove fuel pump being careful not to lose or damage shims between pump and crankcase. Refer to Fig. F2-7 for a cross-sectional view of pump.

Before installing fuel pump, measure plunger height (H – Fig. F2-7) and distance from pump mounting surface on crankcase to pump lobe base circle on camshaft. Install shims between pump and crankcase so plunger height is 1 mm (0.040 inch) greater than distance from crankcase surface to cam. For instance, if plunger height is 62.5 mm (2.460 inches) and distance from crankcase to cam is 61.0 mm (2.400 inches), then a 0.5 mm (0.020 inch) shim would be installed. Do not overtighten mounting screws when installing pump. Bleed fuel system as previously outlined after connecting fuel lines.

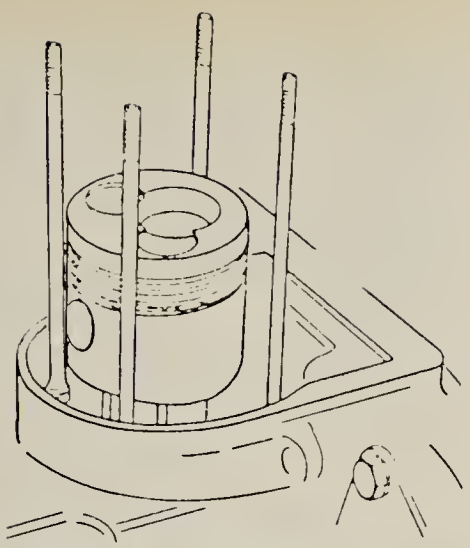

Fig. F2-8—Install piston so indentations in crown are positioned as shown.

INJECTOR

R&R AND OVERHAUL. To remove injector, first clean dirt from injector, injection line, return line and cylinder head. Disconnect return line and injection line and immediately cap or plug all openings. Remove injector.

If a suitable test stand is available, injector may be checked.

WARNING: Fuel leaves the injection nozzle with sufficient force to penetrate the skin. When testing, keep yourself clear of nozzle spray.

Only clean, approved testing oil should be used to test injector. When operating properly during test, injector nozzle will emit a buzzing sound and cut off quickly with no fluid leakage at seat. Opening pressure should be (17720 kPa (2570 psi).

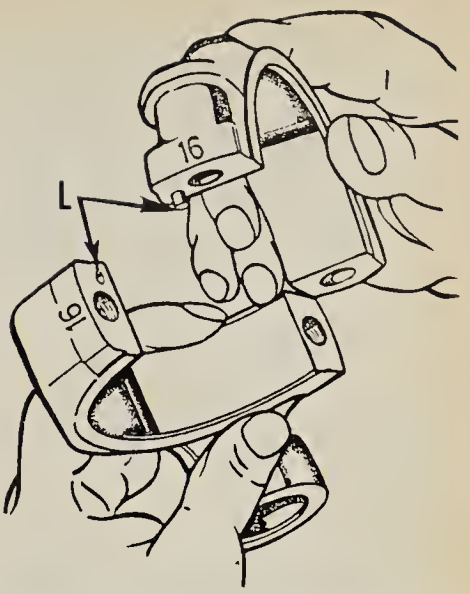

Fig. F2-9—Assemble cap on rod so locating pin and hole (L) are properly mated.

Thoroughly clean all injector components in a suitable solvent. Clean inside orifice end of nozzle tip with a wooden cleaning stick. When reassembling injector, make certain all components are clean and wet with clean diesel fuel oil.

INJECTION PUMP

R&R AND OVERHAUL. To remove injection pump, clean area around injection pump, disconnect all fuel lines from pump and immediately cap or plug all openings to prevent contamination. Remove crankcase breather, then reach through crankcase opening and disconnect governor link from pump. Unscrew pump retaining screws and remove pump being careful not to lose or damage shim gaskets (G – Fig. F2-2).

The injection pump should be tested and overhauled by a shop qualified in diesel fuel injection pump repair.

When installing pump, engage governor link with pump control rack. Tighten injection pump mounting screws to torque specified in TIGHTENING TORQUES section. If pump is renewed or overhauled, or if original shim gaskets are not use, refer to INJECTION PUMP TIMING section and adjust pump timing.

CYLINDER, PISTON, PIN AND RINGS

R&R AND OVERHAUL. The cylinder is removable after removing cylinder head. After cylinder is removed, cover crankcase opening to prevent entry of foreign material. Detach snap rings retaining piston pin, remove piston pin, then separate piston from connecting rod. Do not interchange com-

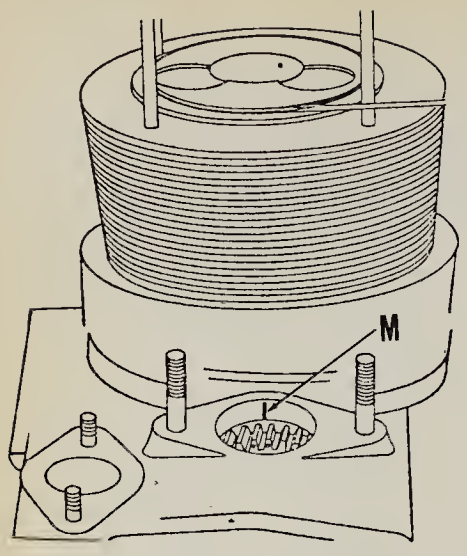

Fig. F2-10—Camshaft gear mark on single-cylinder models must align with mark (M) in tappet housing opening in crankcase when piston is at top dead center.

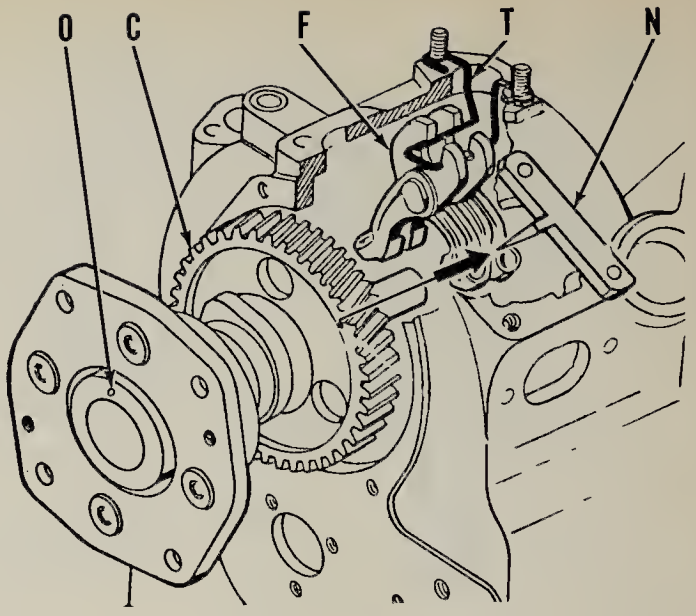

Fig. F2-11—Install tools 7480634 (T) and 7480676 (N) as outlined in text for twin-cylinder camshaft service.

C. Camshaft gear
F. Cam followers
N. Tool 7480676
O. Camshaft "O" mark
T. Tool 7480634

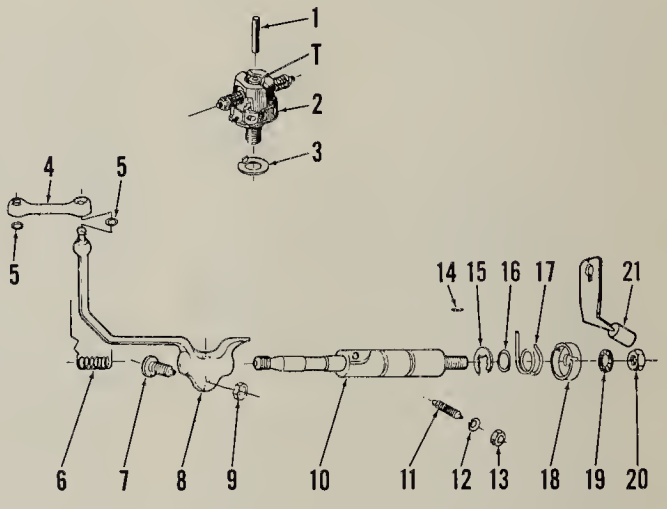

Fig. F2-12—Exploded view of single-cylinder model governor mechanism. Twin-cylinder models are similar.

1. Pin
2. Flyweight assy.
3. Tab washer
4. Link
5. Clips
6. Governor spring
7. Screw
8. Governor arm
9. Nut
10. Shaft
11. Stud
12. Lockwasher
13. Nut
14. Pin
15. "E" ring
16. "O" ring
17. Spring
18. Spring retainer
19. Lockwasher
20. Nut
21. Lever

ponents between cylinders on twin-cylinder models.

Nominal standard cylinder bore diameter is 80.02-80.04 mm (3.1504-3.1512 inches) on Model 25A430, 105.00-105.02 mm (4.1338-4.1346 inches) on Model 95A437, and 95.04-95.06 mm (3.7417-3.7425 inches) on all other models. Piston ring end gap should be 0.3-1.0 mm (0.012-0.040 inch) on Model 25A430, 0.5-1.5 mm (0.020-0.060 inch) on Model 95A437, and 0.4-1.0 mm (0.016-0.040 inch) on all other models.

Position piston on rod so combustion chamber in piston crown is located as shown in Fig. F2-8 and install piston pin. Compress piston rings and slide cylinder down over piston and studs. With cylinder installed and held against crankcase, position piston at top dead center and measure distance from piston crown to top edge of cylinder. Piston crown height should be 0.7-1.0 mm (0.028-0.040 inch) on Model 25A430, 0.8-1.05 mm (0.031-0.041 inch) on Models 36A430 and 36E435, 0.775-1.05 mm (0.030-0.041 inch) on Model 71A437 and 0.775-1.075 mm (0.030-0.042 inch) on Model 95A437.

CONNECTING ROD

REMOVE AND REINSTALL. The connecting rod and crankshaft on Model 25A430 are a unit assembly; refer to crankshaft section for removal. To remove connecting rod on all other models, remove cylinder(s), then remove crankcase side cover. Reach through cover opening, unscrew rod cap retaining screws, remove rod cap through side cover opening and remove rod and piston.

Models 36A430 and 36E435 are equipped with a roller type rod bearing while Models 71A437 and 95A437 are equipped with an insert type bearing. Undersize rod bearings are available for Models 71A437 and 95A437. Standard crankpin journal diameter is 64.985-65.015 mm (2.5585-2.5596 inches) on Model 71A437 and 74.985-75.015 mm (2.9522-2.9533 inches) on Model 95A437 with a bearing clearance of 0.03-0.05 mm (0.0012-0.0020 inch) for both models.

Reverse removal procedure to install connecting rod. Be sure locating pin and hole (L–Fig. F2-9) are properly mated when installing rod cap on rod. Tighten rod screws to 80 N·m (60 ft.-lbs.) on Model 95A437 or to 65 N·m (48 ft.-lbs.) on all other models.

CAMSHAFT AND TAPPETS

Single-Cylinder Models

REMOVE AND REINSTALL. To remove camshaft, remove cylinder head and push rod tube. Unscrew retaining nuts and remove tappet housing from crankcase. Remove fuel injection pump. Unscrew camshaft bearing housing screws and remove camshaft assembly. If bearing housing will not remove easily, jackscrews may be threaded into holes provided in housing to push housing free.

Inspect cam lobes and renew camshaft if excessively worn or damaged. Remove snap rings to separate bearing from camshaft bearing housing. The gear end of the camshaft rides in a bushing in the crankcase and is accessible after removing crankshaft. Inspect tappets and tappet housing bores.

Reassembly is reverse of disassembly. When reinstalling camshaft assembly in crankcase, rotate crankshaft so piston is at top dead center, then insert camshaft so mark on camshaft gear is aligned with mark (M–Fig. F2-10) in tappet housing opening of crankcase. On Model 25A430, the camshaft mark will be slightly to left of crankcase mark (M).

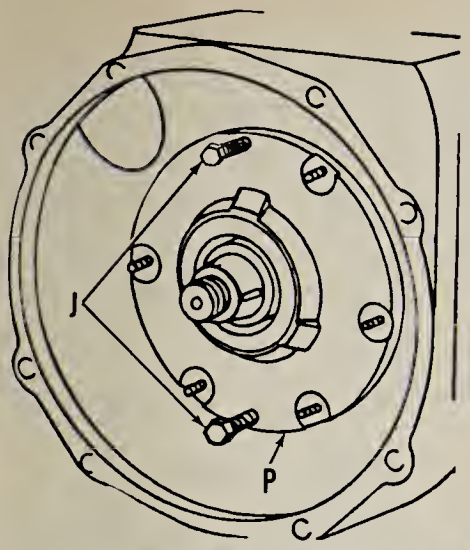

Fig. F2-13—Main bearing support (P) may be dislodged using jackscrews (J) in holes provided.

Twin-Cylinder Models

REMOVE AND REINSTALL. To remove the camshaft on twin-cylinder models, remove cylinder heads, push rod tubes and compression release assembly. Install tool number 7480634 (T–Fig. F2-11) in compression release opening and attach tool to cam followers so followers are held away from cam lobes. Remove fuel injection pump, fuel transfer pump and oil dipstick. Rotate camshaft so "O" mark (O) on camshaft end is towards top of engine. Unscrew camshaft bearing assembly. If bearing housing will not remove easily, jackscrews may be threaded into holes provided in housing to push housing free.

Inspect cam lobes and renew camshaft if excessively worn or damaged. Inspect tappets and tappet housing bores.

Reassembly is reverse of disassembly. When installing camshaft assembly in crankcase, place tool number 7480676 (N–Fig. F2-11) in rear injection pump mounting holes as shown in Fig. F2-11. Rotate crankshaft so number 1 piston is at top dead center on exhaust stroke.

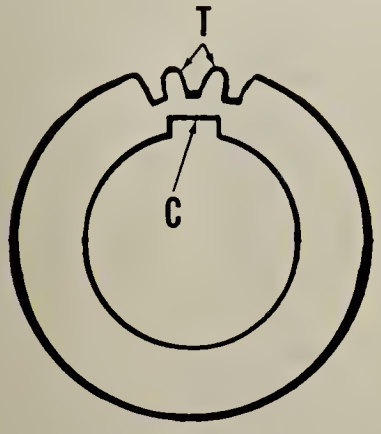

Fig. F2-14—When viewed from end of crankshaft, crankshaft gear keyway (C) should be centered between two gear teeth (T).

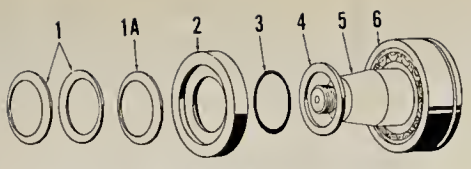

Fig. F2-15—Exploded view of thrust ring components. Belleville washer (1A) is only used on Model 95A437.

1. Belleville washers
1A. Belleville washer
2. Thrust ring
3. "O" ring
4. Thrust washer
5. Crankshaft
6. Bearing

Insert camshaft assembly and mate camshaft and crankshaft gears so mark on camshaft gear is aligned with pointer on tool (N). Remove special tools and complete assembly.

GOVERNOR

Single-Cylinder Models

REMOVE AND REINSTALL. To remove governor, remove breather on top of crankcase then reach through opening and disconnect governor link (4–Fig. F2-12) from injection pump. Detach speed control lever (21), spring retainer (18) and spring (17) from shaft (10). Remove crankcase end cover adjacent to camshaft end. Unscrew and remove stud (11) from shaft. Detach "E" ring (15) and withdraw governor shaft (10) from side of crankcase while removing governor fork (8) assembly through end of crankcase. Remove pin (1), turn governor flyweight stud (T) clockwise (left-hand threads) and remove governor flyweight assembly.

Flyweight assembly is designed according to engine governed speed and is available as a unit assembly. Be sure correct flyweight assembly is installed.

Reverse disassembly procedure to install governor components. Long end of governor spring (6) must engage notch in crankcase while short end of spring is against back side of governor arm (8) so spring tension will force fork arm towards end of crankcase. With all governor components installed, adjust position of screw (7) as follows: Rotate crankshaft so flyweights (2) are positioned with mating surfaces vertical. Loosen locknut (9). Using a small screwdriver, spread flyweights apart as far as they will go. Turn screw (7) so it just contacts pin (1), release flyweights, then turn screw in an additional ½ turn. Without disturbing screw, tighten locknut.

Twin-Cylinder Models

REMOVE AND REINSTALL. Governor service is similar to single-cylinder governor outlined in preceding section. However, governor is mounted on oil pump and governor/oil pump assembly is removed as a unit through crankcase end cover opening. Separate governor from oil pump after removal. Carefully align oil pump mounting screw holes when installing governor/oil pump assembly. Reverse disassembly procedure to install governor. Refer to single-cylinder governor section and adjust position of screw (7–Fig. F2-12) as outlined.

CRANKSHAFT AND CRANKCASE

R&R AND OVERHAUL. To remove crankshaft, remove camshaft, flywheel, governor and connecting rod (On Model 25A430 the connecting rod must remain with crankshaft). Unscrew main bearing support nuts and remove main bearing support (P–Fig. 2-13). If main bearing support will not remove easily, jackscrews (J) may be threaded into holes provided in support to push support free from crankcase. Remove crankshaft.

The governor end of crankshaft on Models 71A437 and 95A437 is supported by a bushing. Standard crankshaft journal diameter at governor end should be 64.985-65.015 mm (2.5585-2.5596 inches) on Model 71A437 or 79.985-80.015 mm (3.1490-3.1502 inches) on Model 95A437. Clearance between crankshaft journal and bushing should be 0.04-0.08 mm (0.0016-0.0032 inch). Bushing is available in standard size and in 0.5 and 1.0 mm undersizes.

Flywheel end main bearing on Models 71A437 and 95A437, and main bearings on all other models are antifriction type bearings. Inspect bearings and crankshaft on all models and renew if damaged or excessively worn. Inner bearing races should be heated to approximately 100°C (212°F) before installation on crankshaft. The crankshaft gear is removable and should be heated to approximately 180°C (360°F) before installation on crankshaft. Install crankshaft gear so when gear is viewed from crankshaft end, keyway (K–Fig. F2-14) is centered on two gear teeth (T).

Connecting rod, rod bearing and crankshaft are a unit assembly on Model 25A430 and individual components may not be serviced separately.

Reverse removal procedure for installation. Tighten main bearing support retaining nuts to 30 N·m (22 ft.-lbs.). Note assembly of thrust ring components at flywheel end as shown in Fig. F2-15. Outer circumference of thrust ring should be smooth as it contacts crankcase oil seal. Install Belleville washers (1) so concave sides face each other. Belleville washer (1A) is only used on Model 95A437 and must be installed with concave face towards thrust ring (2).

KIRLOSKAR

1401 Cherry Hill Road
Baltimore, Maryland 21225

Model	No. Cyls.	Bore	Stroke	Displ.
KA-27	1	68 mm (2.677 in.)	76 mm (2.992 in.)	276 cc (16.8 cu. in.)

Model KA-27 is an air-cooled, single-cylinder diesel engine. Crankshaft rotation may be clockwise or counterclockwise depending on application.

MAINTENANCE

LUBRICATION

Recommended crankcase oil is SAE 10W for temperatures below 5°C (41°F), SAE 30 for temperatures between 5°C (41°F) and 35°C (95°F) or SAE 40 for temperatures above 35°C (95°F). Crankcase oil should pass specifications for MIL-L-2104A. Crankcase oil capacity is 1.8 liters (1.9 quarts).

Oil is pressure fed to engine components by a gear type pump. Oil pressure should be 245-294 kPa (35-43 psi) with engine warm and running at operating speed. An oil pressure gage may be connected after removing plug inside of oil filter housing. To adjust oil pressure, remove oil filter housing and turn adjusting screw in back of filter housing.

The renewable oil filter element should be renewed after every 500 hours of operation.

ENGINE SPEED ADJUSTMENT

To adjust idle speed, remove cover (C–Fig. KR1-1), loosen locknut, then turn idle speed screw (I). Idle speed should be 1200-1500 rpm. Do not turn out screw (I) too far as it must remain in contact with lug on governor arm so engine can be stopped. Maximum speed on variable speed models is adjusted by turning high speed adjusting screw (H–Fig. KR1-2). Maximum governed speed under load should be 1500, 2000, 2500, 2800, 3000 or 3600 rpm depending on engine application.

FUEL SYSTEM

FUEL FILTER. A renewable fuel filter is located below fuel tank on side of engine. Manufacturer recommends renewing fuel filter element after every 500 hours of operation.

BLEED FUEL SYSTEM. Due to gravity feed type of fuel system, air should be bled from system as fuel injection pump operates. However, bleeding time may be shortened by loosening then retightening fuel line fittings, starting first at fuel tank and working to fuel injection pump. Retighten fittings when air-free fuel flows.

INJECTION PUMP TIMING. Injection pump timing adjusted using shims (G–Fig. KR1-3). To check injection pump timing, proceed as follows: Disconnect high pressure line from injection pump, then unscrew delivery valve holder (H) and remove spring and delivery valve assembly. Reinstall

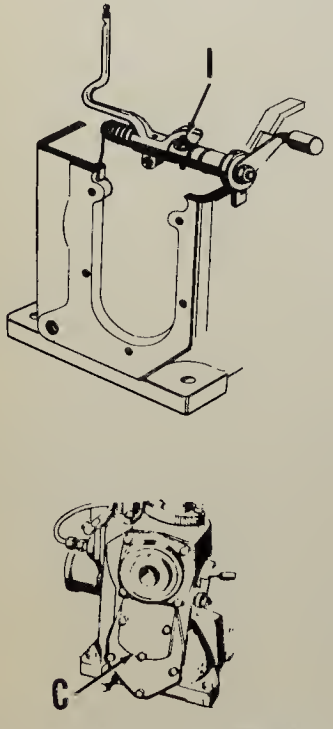

Fig. KR1-1—Remove cover (C) for access to idle speed screw (I) on governor. Refer to text.

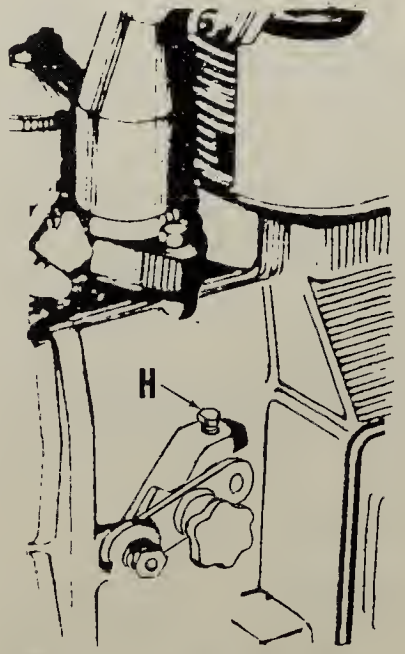

Fig. KR1-2—High speed on variable speed engines is adjusted by turning adjusting screw (H).

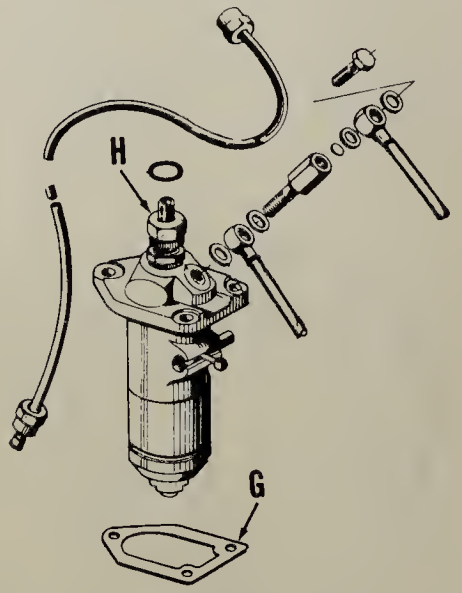

Fig. KR1-3—Injection timing is adjusted by varying thickness of shim gasket (G). Refer to text for timing procedure.

delivery valve holder (H) and connect a suitable spill pipe to valve holder. Aim spill pipe at a receptacle to catch discharged fuel. Move throttle control to full speed position. Rotate engine flywheel slowly in running direction (engines are designed for clockwise or counterclockwise rotation) until fuel just stops flowing from spill pipe. Note rated rpm of engine and refer to following table for desired injection timing:

Rated Rpm	Injection Timing
1500	24°BTDC
2000	24°BTDC
2500	28°BTDC
2800	28°BTDC
3000	31°BTDC
3600	34°BTDC

If injection timing is incorrect, remove injection pump and remove or install shims (G) as required. Adding shims will retard injection timing while removing shims advances injection timing. Be sure to reassemble delivery valve in pump after testing.

AIR FILTERS

Manufacturer recommends cleaning air filter after every 50 hours of operation and renewing filter after 500 hours.

REPAIRS

TIGHTENING TORQUES

Refer to the following table for special tightening torques.

Connecting rod ..... 40 N·m (30 ft.-lbs.)
Cylinder head ..... 40 N·m (30 ft.-lbs.)
Flywheel ..... 176 N·m (130 ft.-lbs.)
Injection pump ..... 25 N·m (18 ft.-lbs.)
Injector retainer plate ..... 25 N·m (18 ft.-lbs.)
Main bearing support ..... 25 N·m (18 ft.-lbs.)
Rocker arm stand ..... 78 N·m (58 ft.-lbs.)

VALVE CLEARANCE

Valve clearance may be adjusted after removing rocker arm cover. Rotate crankshaft until piston is at top dead center on compression stroke, then turn rocker arm adjusting screws until appropriate thickness feeler gage can be inserted between rocker arm and end of valve stem. Recommended clearance is 0.10 mm (0.004 inch) for intake and 0.15 mm (0.006 inch) for exhaust with engine cold.

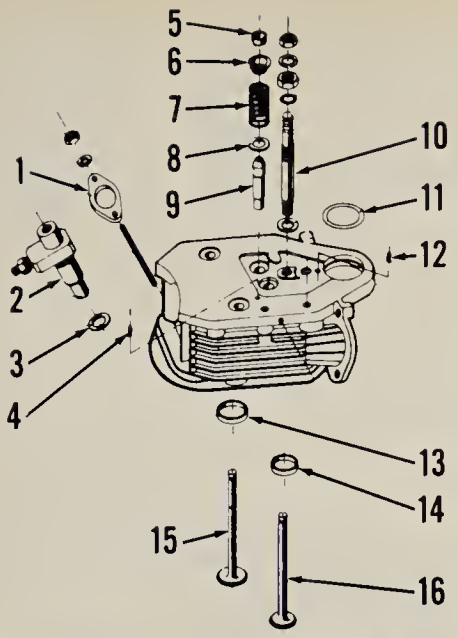

Fig. KR1-4—Exploded view of cylinder head. Rocker arm assembly is not shown.

1. Injector retainer
2. Injector
3. Copper washer
4. Dowel
5. Keys
6. Spring retainer
7. Valve spring
8. Washer
9. Valve guide
10. Rocker stand stud
11. Push pin rod tube seal
12. Dowel
13. Intake valve seat
14. Exhaust valve seat
15. Intake valve
16. Exhaust valve

CYLINDER HEAD AND VALVE SYSTEM

Valve face and valve seat angles are 45° for intake and exhaust. Valve seat width should be 2.05-2.33 mm (0.080-0.090 inch). Valve seats are renewable. Intake valve stem diameter is 8.956-8.968 mm (0.3526-0.3530 inch) and exhaust valve stem diameter is 8.918-8.930 mm (0.3511-0.3515 inch). Intake and exhaust valve guide inside diameter is 9.013-9.035 mm (0.3548-0.3557 inch). Intake valve stem clearance is 0.045-0.079 mm (0.0018-0.0031 inch) and exhaust valve stem clearance is 0.083-0.117 mm (0.0033-0.0046 inch). Maximum valve stem clearance for both valves is 0.15 mm (0.006 inch). Valve guides are renewable. Valve guide outer diameter is 12.050-12.062 mm (0.4744-0.4749 inch) and cylinder head bore is 12.000-12.027 mm (0.4724-0.4735 inch).

Clearance between rocker shaft and rocker arm bushing should be 0.065-0.101 mm (0.0025-0.0040 inch). Maximum allowable clearance is 0.15 mm (0.006 inch).

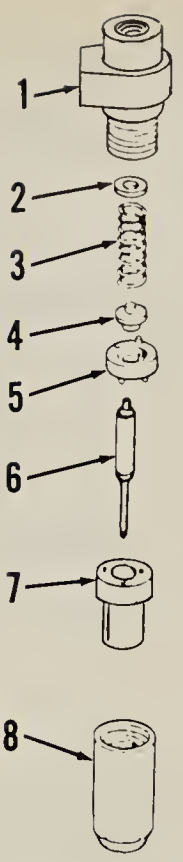

Fig. KR1-5—Exploded view of injector.

1. Body
2. Shim
3. Spring
4. Push pin
5. Spacer
6. Valve
7. Nozzle
8. Nozzle holder

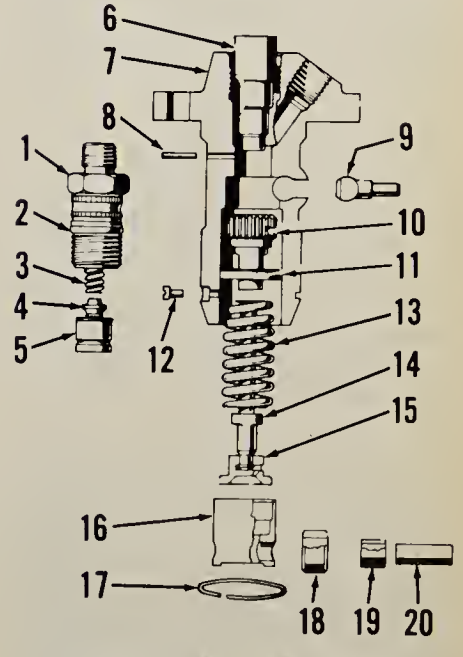

Fig. KR1-6—View of injection pump.

1. Delivery valve holder
2. "O" ring
3. Spring
4. Delivery valve
5. Delivery valve seat
6. Barrel
7. Pump body
8. Pin
9. Control rack
10. Pinion
11. Spring seat
12. Pin
13. Spring
14. Plunger
15. Spring retainer
16. Tappet
17. Retaining ring
18. Outer roller
19. Inner roller
20. Pin

Tighten cylinder head nuts in a crossing pattern to 40 N·m (30 ft.-lbs.). Measure clearance between piston at

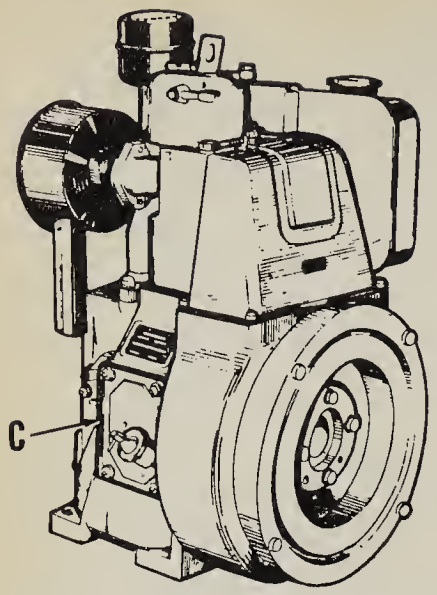

Fig. KR1-7—Remove cover (C) for access to connecting rod.

top dead center and cylinder head by inserting a lead wire (solder) or other suitable tool through injector opening in head. Clearance between head and piston should be 0.7-0.8 mm (0.028-0.031 inch). Head gaskets are available in varying thicknesses to adjust clearance. Note that push rod nearer cylinder operates exhaust valve while outer push rod operates intake valve. Tighten rocker arm stand nut to 78 N·m (58 ft.-lbs.).

INJECTOR

REMOVE AND REINSTALL. To remove injector, first clean dirt from injector, injection line, return line and cylinder head. Disconnect return line and injection line and immediately cap or plug all openings. Remove injector retainer plate and carefully withdraw injector from head.

Use a new copper washer (3—Fig. KR1-4) when installing injector. Tighten nuts securing injector retainer plate to 25 N·m (18 ft.-lbs.).

TESTING. WARNING: Fuel leaves the injection nozzle with sufficient force to penetrate the skin. When testing, keep yourself clear of nozzle spray.

If a suitable test stand is available, injector operation may be checked. Only clean, approved test oil should be used to test injector. When operating properly during test, injector nozzle will emit a buzzing sound and cut off quickly with no fluid leakage at seat.

Opening pressure with a new spring (3—Fig. KR1-5) should be 14220-14710 kPa (2060-2135 psi) while opening

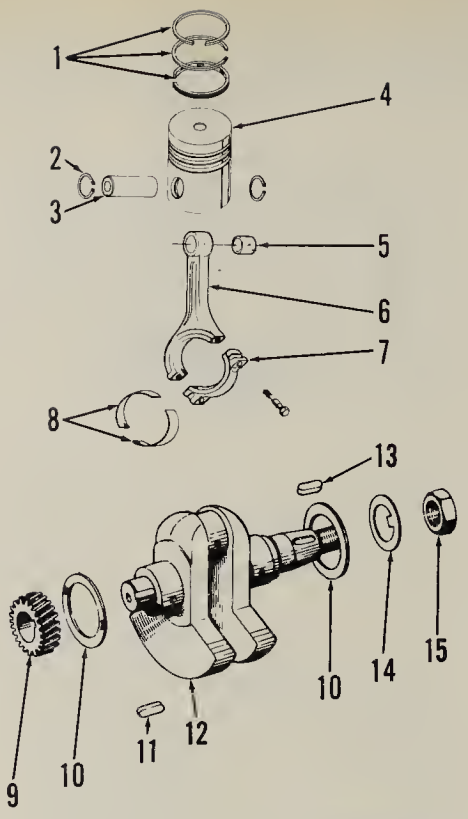

Fig. KR1-8—Exploded view of crankshaft assembly.

1. Piston rings
2. Snap ring
3. Piston pin
4. Piston
5. Bushing
6. Connecting rod
7. Rod cap
8. Rod bearing
9. Gear
10. Thrust washers
11. Key
12. Crankshaft
13. Key
14. Tab washer
15. Nut

pressure with a used spring should be approximately 13240 kPa (1920 psi). Opening pressure is adjusted by varying number and thickness of shims (2). Valve should not show leakage at orifice spray holes for 10 seconds at 12260 kPa (1780 psi).

OVERHAUL. Clamp injector body (1—Fig. KR1-5) in a vise with nozzle tip pointing upward. Remove nozzle holder nut (8). Remove nozzle (7) with valve (6) and spacer (5). Invert injector body (1) and remove push pin (4), spring (3) and shims (2). Thoroughly clean all parts in a suitable solvent. Clean inside orifice end of nozzle with a wooden cleaning stick. Orifice spray holes may be cleaned by inserting a cleaning wire slightly smaller than spray holes.

When reassembling injector, make certain all components are clean and wet with clean diesel fuel oil. Tighten nozzle nut (8) to 59 N·m (44 ft.-lbs.).

INJECTION PUMP

REMOVE AND REINSTALL. Remove breather adjacent to pump, then reach through breather opening in crankcase and disconnect governor link

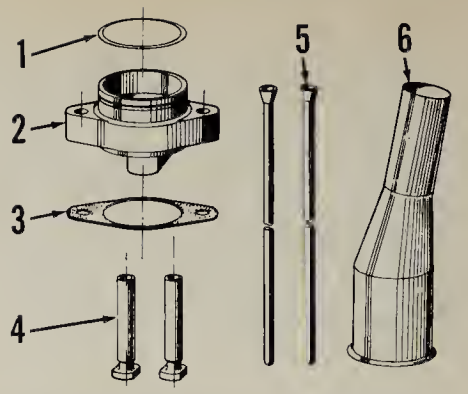

Fig. KR1-9—Exploded view of tappets and push rods.

1. Push rod tube seal
2. Valve tappet guide
3. Gasket
4. Valve tappets
5. Push rods
6. Push rod tube

(4—Fig. KR1-13) from pump. Disconnect fuel lines from pump and immediately cap all openings to prevent contamination. Remove pump being careful not to lose timing shims.

Injection pump should be serviced by a shop experienced in fuel injection pump repair.

Refer to INJECTION PUMP TIMING section after pump installation if original timing shims were not installed or timing is believed incorrect.

CYLINDER, PISTON, PIN AND RINGS

R&R AND OVERHAUL. The cylinder is removable after removing cylinder head as previously outlined. After cylinder is removed, cover crankcase opening to prevent entry of foreign material. Detach snap rings (2—Fig. KR1-8), then use a suitable puller to withdraw piston pin (3). Remove piston from connecting rod.

Piston ring end gap should be 0.25-0.40 mm (0.010-0.015 inch) for compression rings and 0.20-0.35 mm (0.008-0.013 inch) for oil ring. Maximum piston ring end gap is 0.6 mm (0.023 inch) for compression rings and 0.5 mm (0.019 inch) for oil ring. Piston ring side clearance should be 0.11-0.14 mm (0.004-0.005 inch) for top compression ring, 0.09-0.12 mm (0.004-0.005 inch) for second compression ring and 0.05-0.08 mm (0.002-0.003 inch) for oil ring. Maximum ring side clearance is 0.25 mm (0.010 inch) for top compression ring, 0.20 mm (0.008 inch) for second compression ring and 0.15 mm (0.006 inch) for oil ring.

Piston pin bore diameter in piston is 23.996-24.009 mm (0.9447-0.9452 inch) and piston pin outer diameter is 23.996-24.000 mm (0.9447-0.9449 inch). Clearance between piston pin and connecting rod should be 0.030-0.054 mm (0.0012-0.0021 inch); maximum

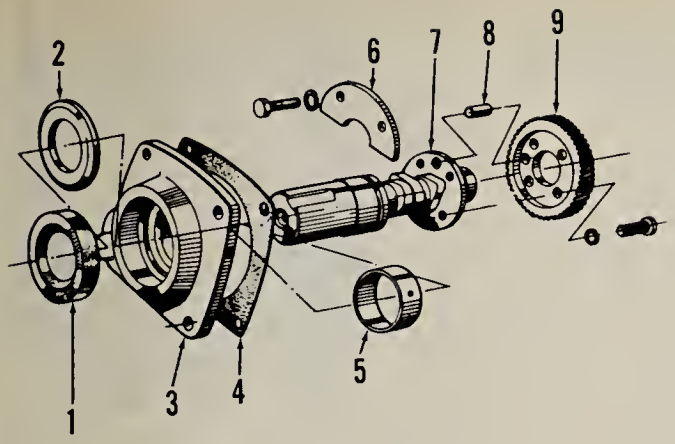

Fig. KR1-10—Exploded view of bushing-supported camshaft used on some engines.

1. Seal
2. Oil deflector
3. Bearing housing
4. Gasket
5. Bushing
6. Thrust plate
7. Camshaft
8. Dowel
9. Gear

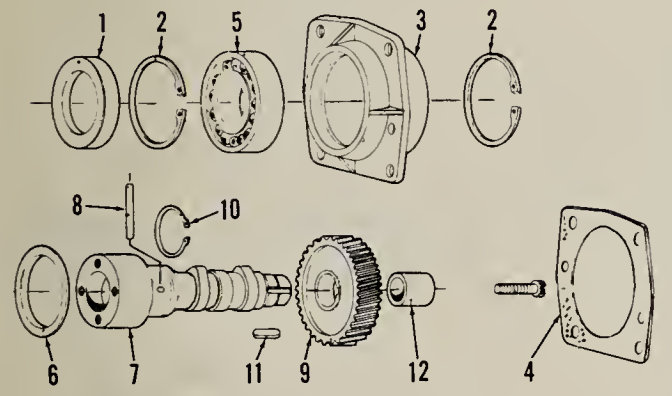

Fig. KR1-11—Exploded view of bearing-supported camshaft used on some models.

1. Seal
2. Snap ring
3. Bearing housing
4. Gasket
5. Bearing
6. Oil deflector
7. Camshaft
8. Starter pin
9. Gear
10. Snap ring
11. Key
12. Sleeve

allowable clearance is 0.15 mm (0.006 inch). Refer to CONNECTING ROD section.

Cylinder standard bore diameter is 68.06-68.08 mm (2.6795-2.6803 inches). Standard piston diameter is 67.97 mm (2.676 inches). Piston clearance should be 0.09-0.11 mm (0.0035-0.0043 inch).

Assembly is reverse of disassembly. Refer to CYLINDER HEAD section for cylinder head installation.

CONNECTING ROD

R&R AND OVERHAUL. To remove connecting rod, remove cylinder as outlined in previous section, then remove side cover (C–Fig. KR1-7) for access to connecting rod big end. Unscrew rod screws and remove rod cap through side cover opening, then remove rod out top of engine.

Connecting rod big end clearance between rod bearing and crankpin should be 0.031-0.083 mm (0.0012-0.0032 inch). Undersize rod bearings are available. The connecting rod small end bushing is renewable. Inner diameter of small end bushing is 24.03-24.05 mm (0.9461-0.9468 inch) and clearance between piston pin and rod bushing should be 0.03-0.054 mm (0.0012-0.0021 inch).

Install piston and rod so numbered side of rod is away from side cover opening. Install rod cap through side cover opening then install and tighten rod cap screws to 40 N·m (30 ft.-lbs.) Attach side cover to crankcase and refer to previous sections for installation of cylinder and cylinder head.

CAMSHAFT, TAPPETS AND PUSH RODS

R&R AND OVERHAUL. To remove push rods and tappets, remove cylinder head and detach push rod tube (6–Fig. KR1-9). Unscrew retaining nuts and remove tappet guide (2) and tappets from crankcase. Remove fuel injection pump. Unscrew camshaft bearing housing (3–Fig. KR1-10 or KR1-11) screws and remove camshaft assembly. If bearing housing will not remove easily, jackscrews may be threaded into holes provided in housing to push housing free.

Two different camshafts are used and are not interchangeable. The camshaft shown in Fig. KR1-10 is supported at outer end by bushing (5) while the camshaft shown in Fig. KR1-11 is supported at outer end by ball bearing (5). To disassemble bushing supported camshaft assembly, remove thrust plate (6–Fig. KR1-10) and slide camshaft out of housing (3). Detach gear (9) from camshaft. Bushing (5) may be renewed if necessary. To disassemble bearing supported camshaft, unscrew Allen screw and remove steel sleeve (12–Fig. KR1-11). Pull gear (9) off shaft, detach snap ring (10) and slide shaft out of bearing (5). Remove snap rings (2) and remove bearing (5) from housing (3).

Inspect components and renew if required. Inner end of camshaft (7–Fig. KR1-10) rides in crankcase bushing while steel sleeve (12–Fig. KR1-11) attached to camshaft (7) rides in crankcase bushing. Clearance between crankcase bushing and camshaft (7–Fig. KR1-10) journal or camshaft sleeve (12–Fig. KR1-11) should not exceed 0.20 mm (0.008 inch). Renew tappet guide (2–Fig. KR1-9) if tappet bores are out-of-round more than 0.05 mm (0.002 inch).

Reassembly is reverse of disassembly. When installing camshaft assembly in crankcase, rotate crankshaft so piston is at top dead center then insert camshaft so "I" mark on gear is aligned with mark in tappet guide opening of crankcase as shown in Fig. KR1-12.

GOVERNOR

R&R AND OVERHAUL. To remove governor, remove breather on top of crankcase then reach through opening and disconnect governor link (4–Fig. KR1-13) from injection pump. Detach speed control lever (21), spring retainer (18) and spring (17) from shaft (10). Remove end cover (E–Fig. KR1-14). Unscrew and remove stud (11-Fig. KR1-13) from shaft. Detach "E" ring (15) and withdraw governor shaft (10) from side of crankcase while removing governor fork (8) assembly through end of crankcase. The governor flyweight assembly (2) may be removed by turning stud (T) after removing pin (1).

Governor flyweight assembly (2) is designed according to engine governed speed and direction of crankshaft rotation. Governed speed may be 1500, 2000, 2500, 2800, 3000 or 3600 rpm. Flyweight assembly is available only as a

Fig. KR1-12—Align "I" mark on camshaft gear with mark (M) on crankcase. Piston must be at TDC. Refer to text.

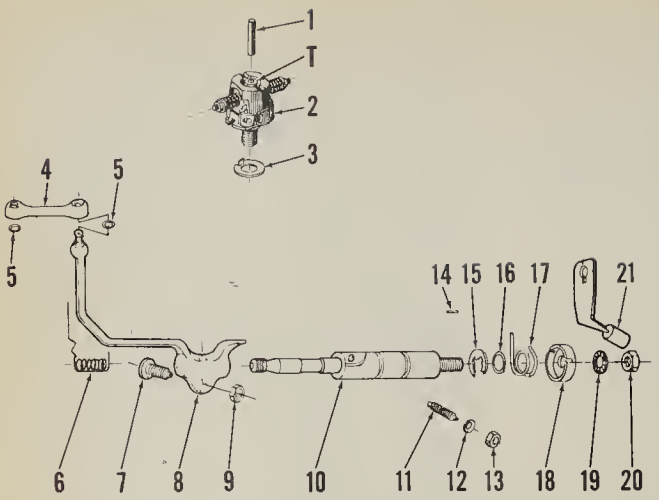

Fig. KR1-13—Exploded view of governor mechanism.

1. Pin
2. Flyweight assy.
3. Tab washer
4. Link
5. Clips
6. Governor spring
7. Screw
8. Governor arm
9. Nut
10. Shaft
11. Idle speed screw
12. Lockwasher
13. Nut
14. Pin
15. "E" ring
16. "O" ring
17. Spring
18. Spring retainer
19. Lockwasher
20. Nut
21. Lever

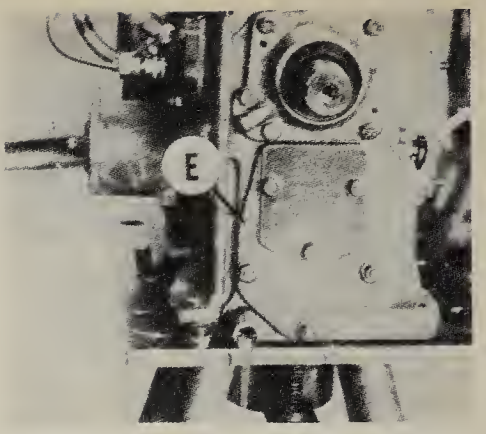

Fig. KR1-14—Remove end cover (E) for access to governor and oil pump.

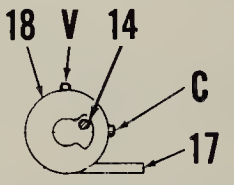

Fig. KR1-15—Position short end of spring (17) in slot (V) of spring retainer on variable speed engines or in slot (C) on constant speed engines.

unit assembly. When installing a new governor, be sure correct flyweight assembly is installed.

Reverse disassembly procedure to install governor components. Long end of governor spring (6) must engage notch in crankcase while short end of spring is against back side of governor arm (8) so spring tension will force fork arm towards end of crankcase. Refer to Fig. KR1-15 when installing spring (17 – Fig. KR1-13) and spring retainer (18). Short end of spring (17) on constant speed engines should engage slot (C – Fig. KR1-15) of spring retainer (18) while short spring end on variable speed engines should engage slot (V). Long end of spring on all engines must engage lug on side of crankcase so lever (21 – Fig. KR1-13) is tensioned upwards. After governor installation, refer to ENGINE SPEED ADJUSTMENT section.

OIL PUMP

R&R AND OVERHAUL. To remove oil pump, remove end cover (E – Fig. KR1-14), then unscrew three Allen screws securing oil pump and remove oil pump. If oil pump is difficult to remove due to binding or a close fit, it will be necessary to remove crankshaft so pump may be tapped loose from inside crankcase.

To disassemble oil pump, detach snap ring (8 – Fig. KR1-16) and remove gear (5). Unscrew oil pump housing screws, then tap gently on shaft to dislodge oil pump components. Oil pump is availalble only as a unit assembly and should be renewed if components are damaged or excessively worn. Gear backlash should not exceed 0.12 mm (0.005 inch). Two different oil pumps are used according to crankshaft rotation. Be sure new pump matches crankshaft rotation.

Reverse disassembly procedure for assembly.

CRANKSHAFT

R&R AND OVERHAUL. To remove crankshaft, unscrew flywheel nut and use a suitable puller to remove flywheel.

NOTE: On engines with clockwise crankshaft rotation, the flywheel nut has left-hand threads. Remove connecting rod and governor as outlined in previous sections. At flywheel end, unscrew bearing support retaining nuts and install jackscrews in holes provided in bearing support. Loosen, then remove bearing support. Withdraw crankshaft from crankcase.

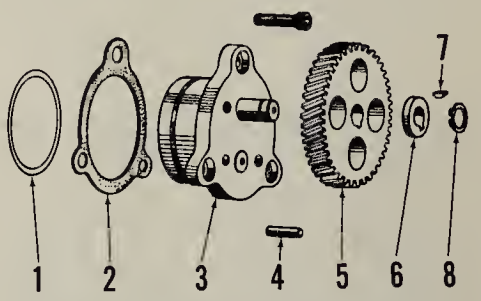

Fig. KR1-16—View of oil pump. Dowel pins (4) are inserted through pump end plates and body.

1. "O" ring
2. Gasket
3. Oil pump
4. Dowel pins (2)
5. Gear
6. Spacer
7. Key
8. Snap ring

Crankshafts are designed for clockwise or counterclockwise rotation. Be sure correct crankshaft is installed if renewal is required.

Use a suitable puller to remove crankshaft gear. Heat gear prior to assembly to ease installation.

Main bearing clearance is 0.053-0.093 mm (0.0020-0.0036 inch). Standard crankpin journal diameter is 39.975-39.991 mm (1.5738-1.5744 inches) and rod bearing clearance is 0.031-0.083 mm (0.0012-0.0032 inch). Undersize main and rod bearings are available.

Crankshaft end play should be 0.15-0.30 mm (0.006-0.012 inch) and is controlled by thrust washers (10 – Fig. KR1-7). Thrust washer thickness is 2.31-2.36 mm (0.091-0.093 inch).

Install crankshaft by reversing removal procedure. Tighten main bearing support nuts to 25 N·m (18 ft.-lbs.).

KUBOTA

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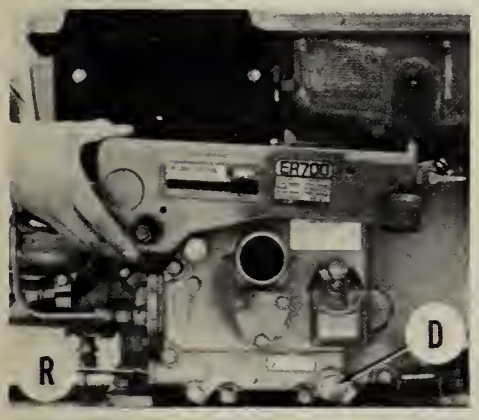
Model	No. Cyls.	Bore	Stroke	Displ.
EA400-N	1	78 mm (3.071 in.)	84 mm (3.307 in.)	401 cc (24.5 cu. in.)
EA400-NB	1	78 mm (3.071 in.)	84 mm (3.307 in.)	401 cc (24.5 cu. in.)
EA450-N	1	84 mm (3.307 in.)	84 mm (3.307 in.)	465 cc (28.4 cu. in.)
EA450-NB	1	84 mm (3.307 in.)	84 mm (3.307 in.)	465 cc (28.4 cu. in.)
EA500-N	1	86 mm (3.386 in.)	90 mm (3.543 in.)	522 cc (31.9 cu. in.)
EA500-NB	1	86 mm (3.386 in.)	90 mm (3.543 in.)	522 cc (31.9 cu. in.)
EA600-N	1	92 mm (3.622 in.)	90 mm (3.543 in.)	598 cc (36.5 cu. in.)
EA600-NB	1	92 mm (3.622 in.)	90 mm (3.543 in.)	598 cc (36.5 cu. in.)



K1-1—View showing location of oil drain plug (D) and oil pressure relief valve (R).

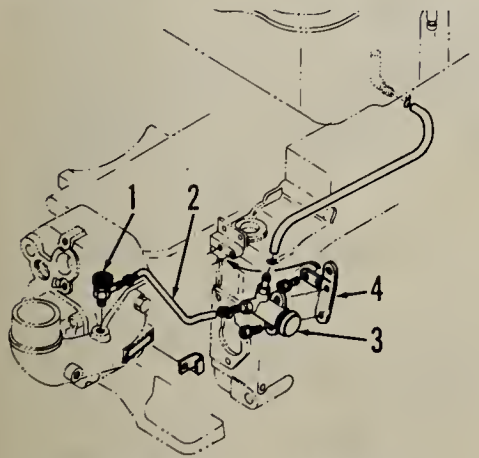
All engines in this section are liquid-cooled, single-cylinder, four-stroke diesel engines. Crankshaft rotation is counterclockwise from flywheel end.

MAINTENANCE

LUBRICATION

Depending on ambient temperature, recommended crankcase oil is SAE 20W, SAE 30 or SAE 10W-30 with API classification CC. Crankcase capacity is 1.9 liters (2 quarts) for Models EA400-N, EA400-NB, EA450-N and EA450-NB or 2.3 liters (2.4 quarts) for all other models.

All models are equipped with a pressure lubrication system. The oil drain plug (D–Fig. K1-1) also serves as the oil pickup and a filter screen is attached to end of drain plug. The drain plug and filter should be removed and filter cleaned and oil renewed after every 100 hours of operation.



K1-2—View of fuel primer circuit.

1. Fuel jet valve
2. Fuel line
3. Primer pump
4. Bracket

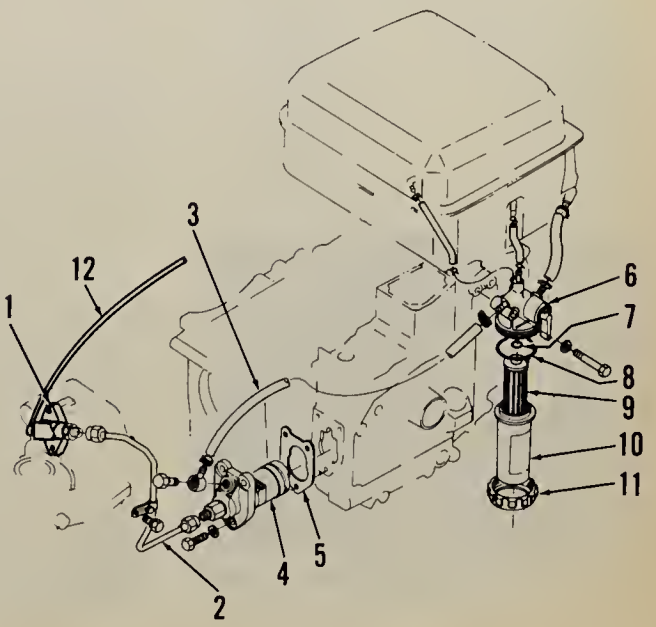


Fig. K1-3—Exploded view of fuel system. Refer to Fig. K1-2 for fuel primer circuit.

1. Injector
2. High pressure fuel line
3. Inlet fuel line
4. Injection pump
5. Shim gasket
6. Fuel valve
7. "O" ring
8. "O" ring
9. Filter
10. Filter canister
11. Nut
12. Fuel return line

FUEL SYSTEM

FUEL PRIMER. All models are equipped with a fuel primer to aid starting. To operate fuel primer, open fuel valve (1 – Fig. K1-2), push primer pump (3) button, then close fuel valve. The primer pump button should be depressed 5 to 6 times for smaller engines and 8 to 9 times for larger engines. Use of primer pump will depend on ambient temperature.

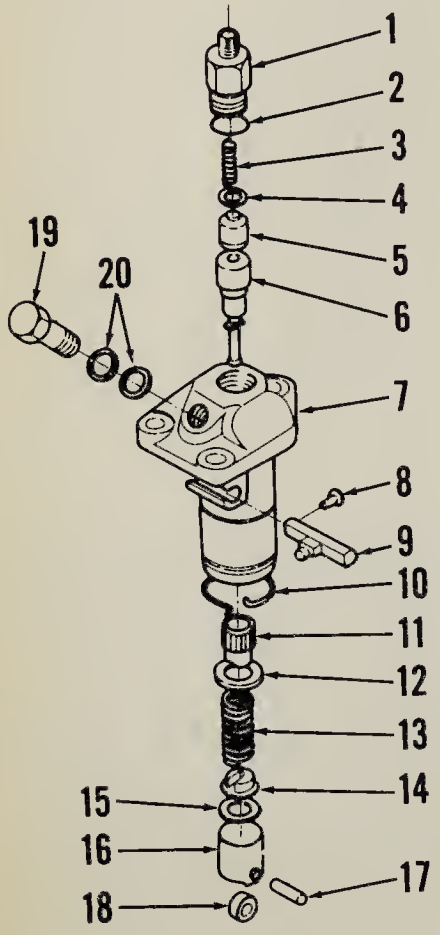


Fig. K1-4—Exploded view of injection pump.

1. Delivery valve holder
2. "O" ring
3. Spring
4. Gasket
5. Delivery valve
6. Plunger
7. Pump body
8. Pin
9. Control rack
10. Clip
11. Control sleeve
12. Washer
13. Spring
14. Spring retainer
15. Shim
16. Tappet
17. Pin
18. Roller
19. Banjo bolt
20. Gaskets

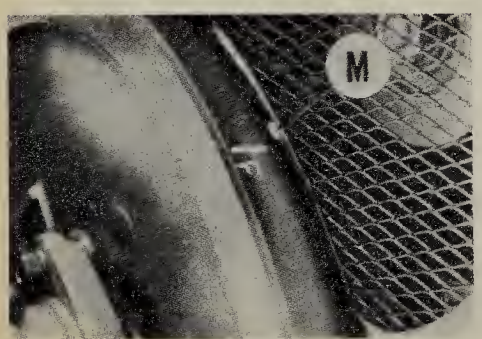


Fig. K1-5—View showing location of timing mark (M) on fan cover.

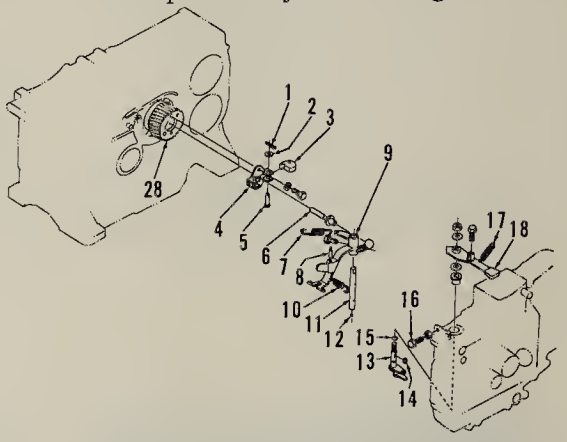
FUEL FILTER. A renewable fuel filter is located below fuel valve as shown in Fig. K1-3. Unscrew nut (11), detach canister (10) and remove filter (9). Manufacturer recommends renewing fuel filter after every 100 hours of operation.

BLEED FUEL SYSTEM. Refer to Fig. K1-3 for view of fuel system. To bleed air from system, first loosen fuel line (3) fitting at injection pump. Open fuel shut-off valve, then retighten fitting when fuel flows from fuel inlet line. Loosen high pressure fuel line (2) to injector (1). Rotate crankshaft to operate injection pump until fuel is discharged from loosened connector. Retighten fitting and start engine.

INJECTION PUMP TIMING. Injection pump timing is adjusted using pump mounting shims (5 – Fig. K1-3). To check injection pump timing proceed as follows: Disconnect high pressure line from injection pump, then unscrew delivery valve holder (1 – Fig. K1-4) and remove valve spring (3) and delivery valve assembly (5). Reinstall delivery valve holder (1) and connect a suitable spill pipe to valve holder. Aim spill pipe at a receptacle to catch discharged fuel. Move throttle control to full speed position. Rotate engine flywheel slowly in counterclockwise direction until fuel just stops flowing from spill pipe. Mark (M – Fig. K1-5) on fan cover should be aligned with "F" mark on flywheel which should provide injection timing of 19-21

Fig. K1-6—Exploded view of governor mechanism. Spring (10) connects to pin (7—K1-6A).

1. Pin
2. Washer
3. Flyweight
4. Weight carrier
5. Pin
6. Push rod
7. Spring
8. Pin
9. Lever
10. Spring
11. Shaft
12. Ball
13. Throttle shaft
14. Key
15. "O" ring
16. Idle speed screw
17. Spring
18. Throttle lever



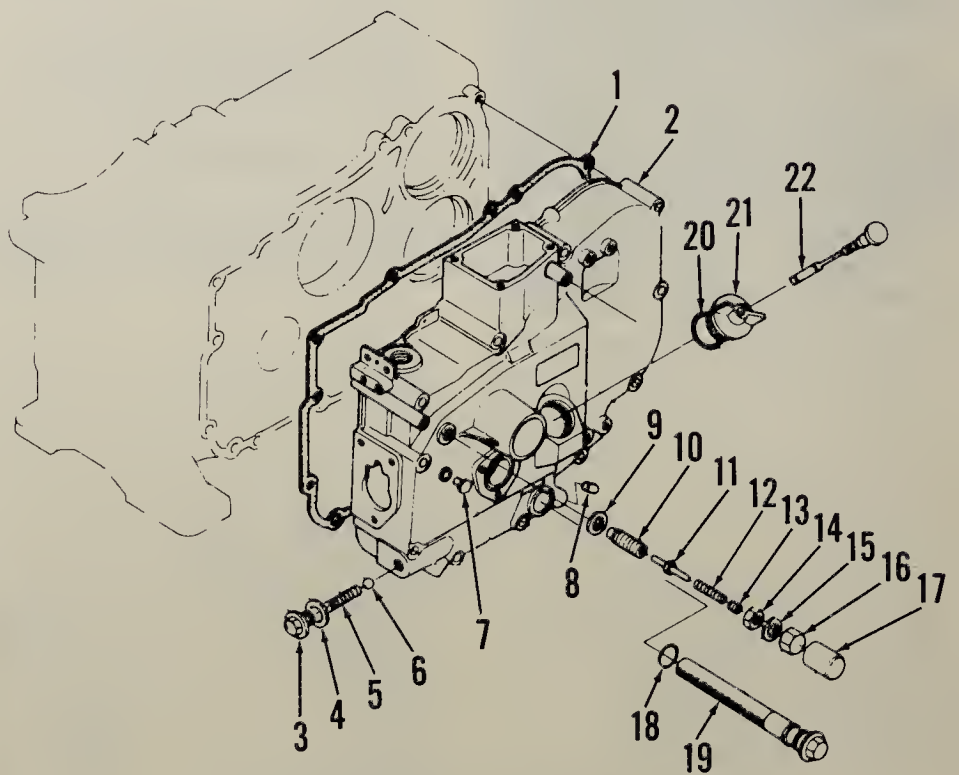


Fig. K1-6A—Exploded view of gearcase components.

1. Gasket
2. Gearcase
3. Plug
4. Gasket
5. Oil pressure relief spring
6. Oil pressure relief ball
7. Pin
8. Plug
9. Gasket
10. Fuel limiter spring housing
11. Pin
12. Spring
13. Screw
14. Nut
15. Gasket
16. Cap nut
17. Cap
18. "O" ring
19. Filter & drain plug
20. "O" ring
21. Fill plug
22. Dipstick

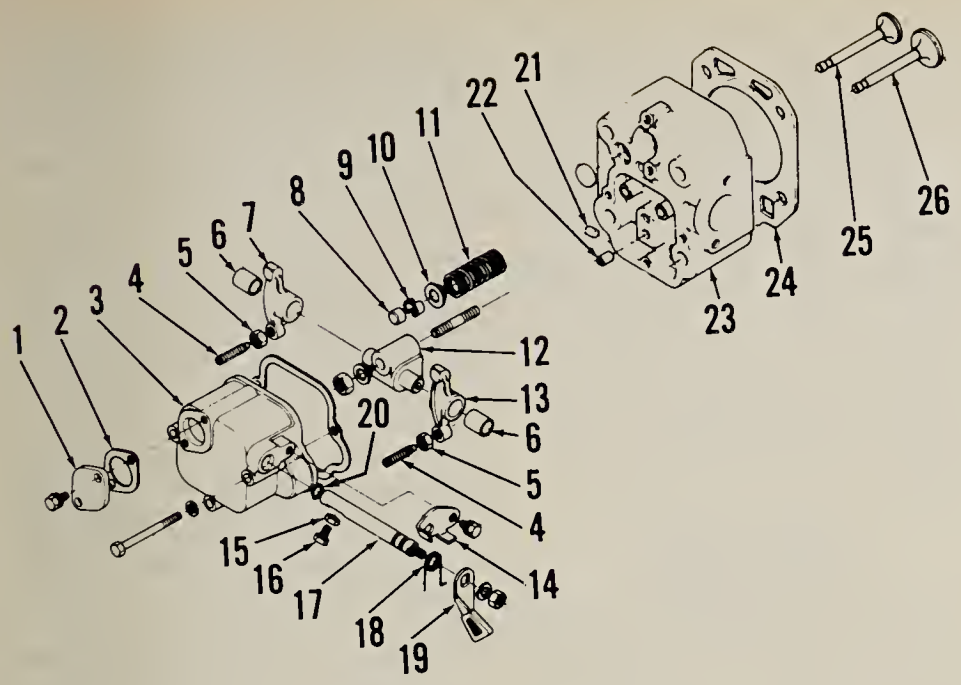


Fig. K1-7—Exploded view of cylinder head.

1. Cover
2. Gasket
3. Rocker arm
4. Adjusting screw
5. Locknut
6. Bushing
7. Rocker arm, ex.
8. Cap
9. Retainer keys
10. Spring retainer
11. Valve spring
12. Rocker stand
13. Rocker arm, int.
14. Bracket
15. Locknut
16. Screw
17. Shaft
18. Spring
19. Compression release lever
20. "O" ring
21. Plug
22. Pin
23. Head
24. Gasket
25. Exhaust valve
26. Intake valve

degrees BTDC. If injection timing is incorrect, remove injection pump and remove or install shims (5 – Fig. K1-3) as required. Adding shims will retard injection timing while removing shims advances injection timing. Each shim alters injection timing approximately 1½ degrees. Tighten injection pump mounting screws to 24-27 N·m (18-20 ft.-lbs.). Reinstall delivery valve and spring and tighten delivery valve holder to 45 N·m (33 ft.-lbs.).

GOVERNOR

All models are equipped with a flyweight type governor attached to the crankshaft gear. Refer to K1-6 for an exploded view of governor mechanism.

Maximum no-load governed speed should be 2540-2580 rpm while low idle speed should be less than 1000 rpm.

Fuel limiting device (components 9 through 17 – Fig. K1-6A) should be adjusted by loosening nut (14) then turning spring housing (10) so excessive smoke is not produced when engine is slightly overloaded.

COMPRESSION RELEASE

All models are equipped with a compression release which holds the exhaust valve open slightly when compression release lever (19 – Fig. K1-7) is rotated. To adjust compression release, rotate engine crankshaft so piston is at top dead center on compression. Remove cover (1), loosen locknut (15 – Fig. K1-8) and back off adjusting screw (16). Rotate compression release lever to engaged position. Turn adjusting screw (16) in until it contacts exhaust rocker arm (7), then turn screw 1½ additional turns. Tighten locknut and check operation of compression release.

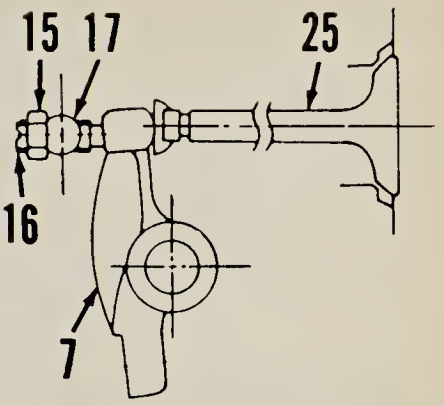


Fig. K1-8—Loosen locknut (15) and turn adjusting screw (16) to adjust compression release. Refer to text.

COOLING SYSTEM

All models are equipped with a liquid type cooling system. A radiator is mounted above the engine and an engine driven fan circulates air through the radiator. Coolant is circulated by thermo-siphon. On "NB" models, alternator coils are mounted behind the fan and the fan also functions as the alternator rotor.

A coolant drain valve is located on underside of the cylinder head. Cooling system capacity is 1.6 liters (1.7 quarts) for Models EA400-N, EA400-NB, EA450-N and EA450-NB or 2.1 liters (2.2 quarts) for all other models. Recommended pressure rating for radiator cap is 88.25 kPa (13 psi).

Fan belt tension should be adjusted so belt deflects 5-10 mm (3/16-⅜ inch) when using finger pressure against belt at midpoint between fan pulley and tension pulley. Relocate tension pulley to adjust belt tension.

AIR FILTER

All models are equipped with a dry type renewable air filter. Manufacturer recommends blowing out filter after every 100 to 200 hours of operation and renewing filter after six cleanings or one year.

REPAIRS

TIGHTENING TORQUES

Refer to the following table for tightening torques.

Connecting rod:
- EA400-N, EA400-NB, EA450-N, EA450-NB....30-34 N·m (22-25 ft.-lbs.)
- All other models.....49-54 N·m (36-40 ft.-lbs.)

Crankcase cover.....9-10 N·m (7-8 ft.-lbs.)

Cylinder head:
- EA400-N, EA400-NB EA450-N, EA450-NB...98-118 N·m (73-87 ft.-lbs.)
- All other models.....137-157 N·m (101-115 ft.-lbs.)

Flywheel.....294-392 N·m (217-289 ft.-lbs.)

Gearcase cover.....24-27 N·m (18-20 ft.-lbs.)

Injection pump.....24-27 N·m (18-20 ft.-lbs.)

Injector.....24-27 N·m (18-20 ft.-lbs.)

Main bearing carrier.....24-27 N·m (18-20 ft.-lbs.)

Rocker arm stand.....40-45 N·m (30-33 ft.-lbs.)

COMPRESSION PRESSURE

Compression pressure at cranking speed (100-200 rpm) should be at least 2530 kPa (377 psi) for Models EA400-N and EA400-NB, 2432 kPa (353 psi) for Models EA450-N and EA450-NB or 2235 kPa (324 psi) for all other models.

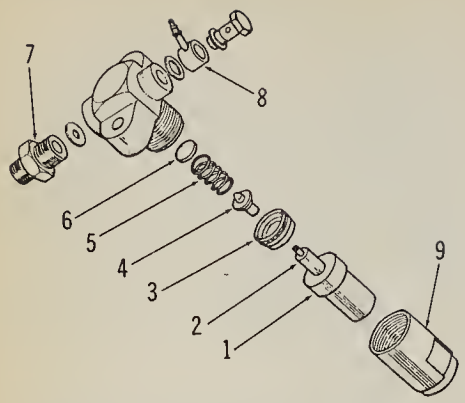


Fig. K1-9—Exploded view of injector.

1. Nozzle body
2. Nozzle valve
3. Spacer
4. Pressure pin
5. Spring
6. Shim
7. Pressure fitting
8. Return fitting
9. Nozzle nut

CYLINDER HEAD

R&R AND OVERHAUL. Drain coolant, remove muffler and disconnect fuel return line from injector. Disconnect both ends of high pressure fuel line. Remove air cleaner and intake pipe. Remove rocker cover (3–Fig. K1-7), then unscrew rocker stand retaining nut and remove rocker arm assembly. Unscrew cylinder head retaining nuts and remove cylinder head.

Check flatness of head surface using a straightedge placed along sides and across mating surface. If a feeler gage of 0.05 mm (0.002 inch) thickness will pass under straightedge, then head must be resurfaced. If head is resurfaced, check valve-to-piston clearance as outlined in following paragraph.

To check valve-to-piston clearance, install head and gasket with valves and springs installed but with injector removed. Tighten head retaining nuts to specified torque of 98-118 N·m (73-87 ft.-lbs.) for Models EA400-N, EA400-NB, EA450-N and EA450-NB or 137-157 N·m (101-115 ft.-lbs.) for all other models. Using a suitable measuring gage such as soft solder or Plastigage, insert gage between each valve and piston crown while rotating crankshaft through top dead center. Minimum allowable valve-to-piston clearance is 0.65 mm (0.026 inch). Note that crush thickness of head gasket should be 1.25-1.45 mm (0.049-0.057 inch) for Models EA400N, EA400-NB, EA450-N and EA450-NB or 1.35-1.55 mm (0.053-0.061 inch) for all other models.

Reverse removal procedure to reinstall cylinder head. Tighten cylinder head nuts to specified torque using a crossing pattern. Tighten rocker arm stand nut to specified torque. Adjust valve clearance as outlined in following section and compression release as outlined in a previous section. Operate engine for 30 minutes, then retorque cylinder heat nuts.

VALVE CLEARANCE

Valve clearance should be adjusted with engine cold and piston at top dead center on compression. Remove rocker cover and turn adjusting screws in rocker arms until appropriate size feeler gage can be inserted between rocker arm and valve stem end. Clearance for both valves is 0.16-0.20 mm (0.006-0.008 inch) for Models EA400-N, EA400-NB, EA450-N and EA450-NB or 0.20-0.23 mm (0.008-0.009 inch) for all other models.

VALVE SYSTEM

Both valves ride directly in cylinder head. Maximum allowable clearance between valve stem and valve guide is 0.1 mm (0.004 inch). Valve guide diameter should be 7.010-7.025 mm (0.2760-0.2765 inch) on EA400-N, EA400-NB, EA450-N and EA450-NB or 8.015-8.030 mm (0.3156-0.3161 inch) for all other models. Valve stem diameter should be 6.960-6.975 mm (0.2740-0.2746 inch) on EA400-N, EA400-NB, EA450-N and EA450-NB or 7.960-7.975 mm (0.3134-0.3140 inch) for all other models.

Valves seat directly in head. Valve seat and face angles are 45 degrees. Valve seat width should be 1.4 mm (0.055 inch). When depth of valve head from cylinder head surface exceeds 1.5 mm (0.059 inch), then head surface should be machined.

Valve springs are interchangeable. Valve spring free length should be 38.5 mm (1.515 inches) while installed height is 33 mm (1.299 inches). Valve spring pressure at installed height should be 66.7 N (15 pounds) with a minimum allowable pressure of 56.9 N (12.8 pounds).

Rocker arm bushings (6–Fig. K1-7) are renewable. Bushing ID should be 14.002-14.050 mm (0.551-0.553 inch). Diameter of rocker stand (12) shafts should be 13.973-13.984 mm (0.5501-0.5505 inch). Maximum clearance between shaft and bushing is 0.15 mm (0.006 inch).

INJECTOR

WARNING: Fuel emerges from injector with sufficient force to penetrate the skin. When testing injector, keep yourself clear of nozzle spray.

REMOVE & REINSTALL. Before removing an injector or loosening injector lines, thoroughly clean injector, lines and surrounding area using compressed air and a suitable solvent.

To remove injector unit, first remove high pressure line leading from pump to injector. Disconnect bleed line by removing banjo bolt or by pulling line from banjo nipple fitting (8–Fig. K1-9). Remove two stud nuts securing ears of injector body to left side of cylinder head and withdraw injector unit.

When installing injector, make sure machined seating surface in cylinder head bore is completely clean and free from carbon buildup. Use a new copper washer underneath injector nozzle. Turn retaining stud nuts both finger tight, then tighten alternately and evenly one-sixth turn at a time to a torque of 24-27 N·m (18-20 ft.-lbs.). Start and run engine, listening for pressure leaks around nozzle seating washer. Correct pressure leaks by checking to be sure stud nuts are tightened evenly and injector unit is not cocked.

TESTING. A complete job of testing and adjusting the injector requires use of special test equipment. Only clean, approved testing oil should be used in tester tank. Nozzle should be tested for opening pressure, seat leakage and spray pattern. When tested, nozzle should open with a high-pitched buzzing sound, and cut off quickly at end of injection with a minimum of seat leakage and a controlled amount of back leakage.

Before conducting test, operate tester lever until fuel flows, then attach injector. Close valve to tester gage and pump tester lever a few quick strokes to be sure nozzle valve is not stuck, and that possibilities are good that injector can be returned to service without disassembly.

OPENING PRESSURE. Open valve to tester gage and operate tester lever slowly while observing gage reading. Opening pressure should be 11770-12260 kPa (1705-1775 psi).

Opening pressure is adjusted by adding or removing shims in shim pack (6–Fig. K1-9). Adding or removing one 0.1 mm (0.004 inch) thickness shim will change opening pressure approximately 980 kPa (140 psi).

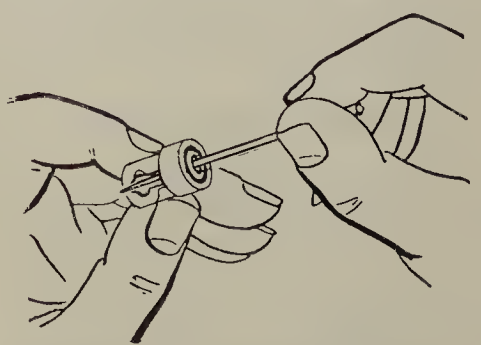


Fig. K1-10—Use a pointed hardwood stick to clean spray hole as shown.

SEAT LEAKAGE. Operate tester lever slowly to maintain a pressure of 1000 kPa (145 psi) below nozzle opening pressure. Observe nozzle tip for leakage. If a drop forms within a period of 10 seconds, nozzle valve is not seating and must be overhauled or renewed.

SPRAY PATTERN. Spray pattern should be well atomized and slightly conical, emerging in a straight axis from nozzle tip. If pattern is wet, ragged or intermittent, nozzle must be overhauled or renewed.

OVERHAUL. Hard or sharp tools, emery cloth, grinding compound or other than approved solvents or lapping compounds must never be used. An approved nozzle cleaning kit is available through a number of specialized sources.

Wipe all dirt and loose carbon from exterior of nozzle and holder assembly. Refer to Fig. K1-9 for exploded view and proceed as follows:

Secure nozzle in a soft-jawed vise or holding fixture and remove cap nut (9). Place all parts in clean calibrating oil or diesel fuel as they are removed.

Clean exterior surfaces with a brass wire brush. Soak injector in an approved carbon solvent, if necessary, to loosen hard carbon deposits. Rinse parts in clean diesel fuel or calibrating oil immediately after cleaning to neutralize the solvent and prevent etching of polished surfaces.

Clean nozzle spray hole from inside using a pointed hardwood stick or wood splinter as shown in Fig. K1-10. Scrape carbon from pressure chamber using hooked scraper as shown in Fig. K1-11. Clean valve seat using brass scraper as shown in Fig. K1-12, then polish seat using wood polishing stick and mutton tallow as in Fig. K1-13.

Reclean all parts by rinsing thoroughly in clean diesel fuel or calibrating oil and assemble while parts are immersed in clean fluid. Make sure adjusting shim pack is intact. Tighten nozzle retaining nut (9–Fig. K1-9) to a torque of 79-98 N·m (58-72 ft.-lbs.). Do not overtighten, distortion may cause valve to stick and no amount of overtightening can stop a leak caused by scratches or dirt. Retest assembled injector as previously outlined.

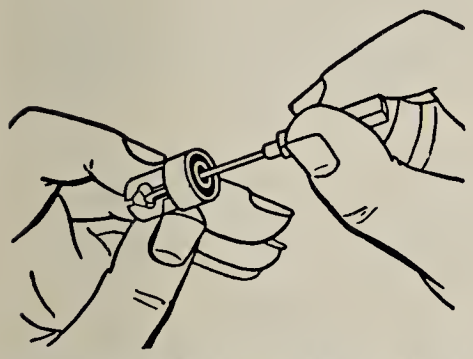


Fig. K1-11—Use a hooked scraper to clean carbon from pressure chamber.

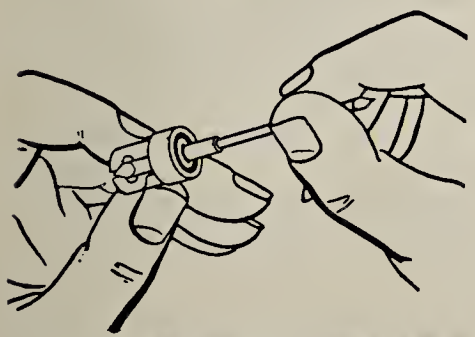


Fig. K1-12—Clean seat using brass scraper as shown.

Fig. K1-13—Polish seat using polishing stick and mutton tallow.

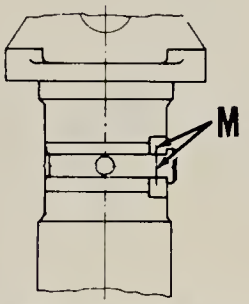


Fig. K1-14—Marks (M) on injection pump body and rack should align.

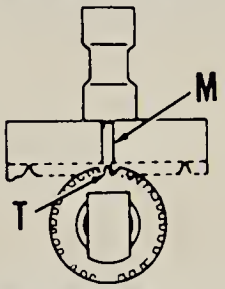


Fig. K1-15—Mark (M) on rack should align with control sleeve master tooth (T).

INJECTION PUMP

All models are equipped with the injection pump shown in Fig. K1-4. The injection pump should be tested and overhauled by a shop qualified for diesel injection pump repair.

If rack (9) is removed and must be reinstalled, marks (M–Fig. K1-14) on pump body and rack must be aligned and master tooth (T–Fig. K1-15) must align with mark (M) on rack.

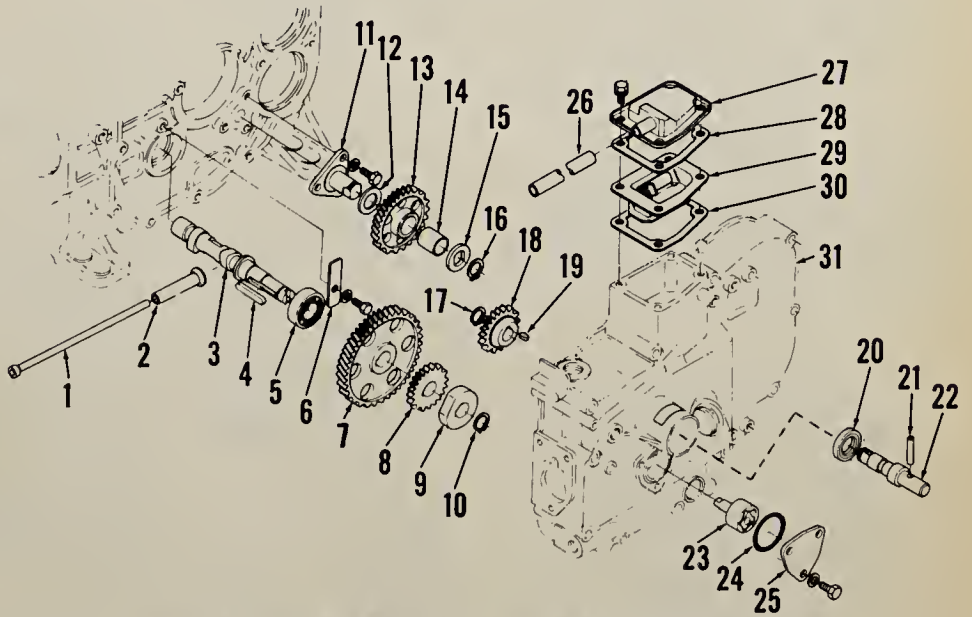


Fig. K1-16—Exploded view of camshaft, idler and oil pump assemblies.

1. Push rod
2. Tappet
3. Camshaft
4. Key
5. Bearing
6. Bearing retainer
7. Gear
8. Gear
9. Injection pump cam
10. Snap ring
11. Idler shaft
12. Washer
13. Idler gear
14. Bushing
15. Slotted washer
16. Snap ring
17. Snap ring
18. Starter gear
19. Key
20. Bearing
21. Pin
22. Starter shaft
23. Oil pump
24. "O" ring
25. Pump cover
26. Hose
27. Breather cover
28. Gasket
29. Breather assy.
30. Gasket
31. Gearcase

The injection pump tappet is actuated by cam (9–Fig. K1-16) which is attached to camshaft (3). Inspect cam each time injection pump is removed.

Tighten injection pump screws to 24-27 N·m (18-20 ft.-lbs.) and refer to INJECTION PUMP TIMING section.

OIL PUMP

R&R AND OVERHAUL. Oil pump (23–Fig. K1-16) is housed in gearcase (31) and driven by a slot in the end of camshaft (3). To remove pump, unscrew cover (25) and extract pump assembly from cover.

The pump is available as a unit assembly only. Note the following measurements to detect pump wear. Inner rotor to outer rotor clearance (Fig. K1-17) should not exceed 0.2 mm (0.008 inch). Outer rotor to gear cover clearance (Fig. K1-18) should not exceed 0.24 mm (0.009 inch). With a straightedge placed across oil pump as shown in Fig. K1-19, gap between either rotor and gear cover should not exceed 0.25 mm (0.010 inch).

The oil pressure relief valve ball (6–Fig. K1-6A) and spring (5) are located in gear cover. Oil pressure is not adjustable. Minimum allowable oil pressure is 196 kPa (28 psi).

GOVERNOR

All models are equipped with a flyweight type governor as shown in Fig. K1-6. The flyweight assembly is attached to crankshaft gear (28) and actuates governor lever (9) which controls the position of fuel injection pump rack (9–Fig. K1-4).

Governor components are accessible after removing gearcase. Inspect components and renew any which are excessively worn or damaged.

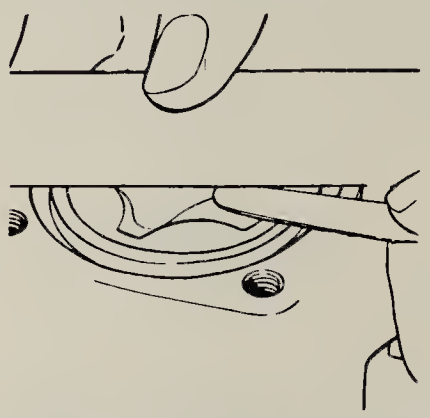


Fig. K1-19—Place a straightedge on oil pump housing and measure between rotor faces and housing. Gap must not exceed 0.25 mm (0.010 inch).

GEAR TRAIN

Should the camshaft gear, crankshaft gear, idler gear or either balancer gear be removed, refer to Fig. K1-20 and align timing marks on gears shown. Note that timing dots are found on camshaft and crankshaft gears while numbers are used on balancer gears. Timing dots and a number are stamped on the idler gear.

BALANCER SHAFTS

R&R AND OVERHAUL. The balancer shafts are accessible after removing gearcase. Remove idler gear (13–Fig. K1-16), then unscrew bearing

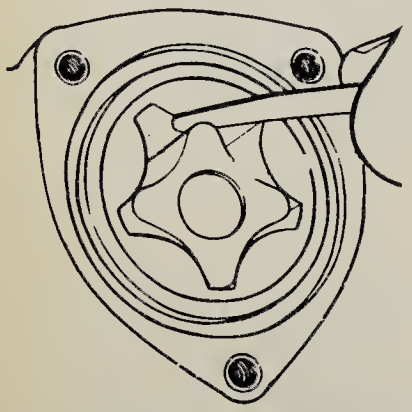


Fig. K1-17—Inner rotor to outer rotor clearance should not exceed 0.2 mm (0.008 inch). Measure as shown.

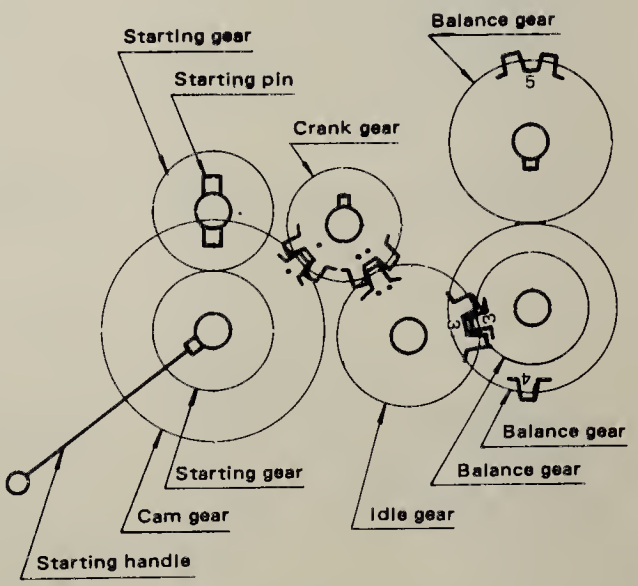


Fig. K1-20—Diagram of gear train showing timing marks.

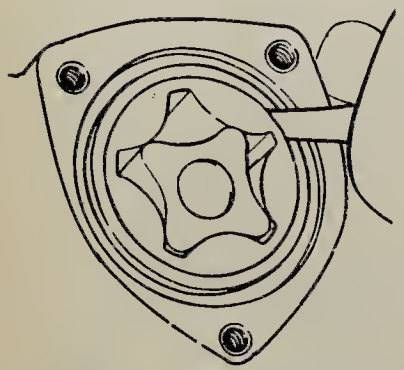


Fig. K1-18—Outer rotor to oil pump housing clearance should not exceed 0.24 mm (0.009 inch). Measure as shown.

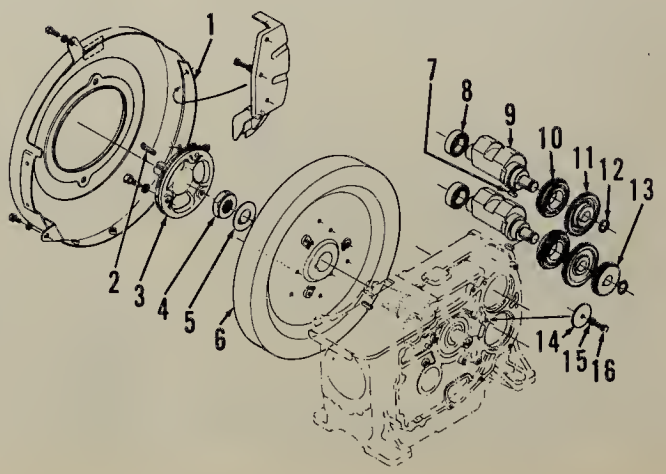


Fig. K1-21—Exploded view of balancer gears and flywheel. On electric start models, a ring gear surrounds flywheel.

1. Cover
2. Pin
3. Rope pulley
4. Nut
5. Lockwasher
6. Flywheel
7. Key
8. Bearing
9. Balancer
10. Bearing
11. Gear
12. Snap ring
13. Gear
14. Bearing retainer
15. Lockwasher
16. Screw

1. Seal housing
2. "O" ring
3. Bearing
4. "O" rings
5. Oil sleeve
6. Snap ring
7. "O" ring
8. Hollow dowel
9. Bearing carrier
10. "O" ring
11. "O" ring
12. Snap ring
13. Washer
14. Bearing
15. Screw
16. Crankshaft
17. Weights
18. Bearing
19. Bushing
20. Retainer
21. Piston pin
22. Piston rings
23. Piston
24. Connecting rod
25. Plug
26. Key
27. Bearing
28. Gear
29. Sleeve
30. "O" rings
31. "O" ring
32. Hollow dowel
33. Plug
34. Hollow dowel
35. "O" ring
36. Coupler
37. Oil pressure light
38. Bearing retainer
39. Cylinder block
40. Gasket
41. Cover

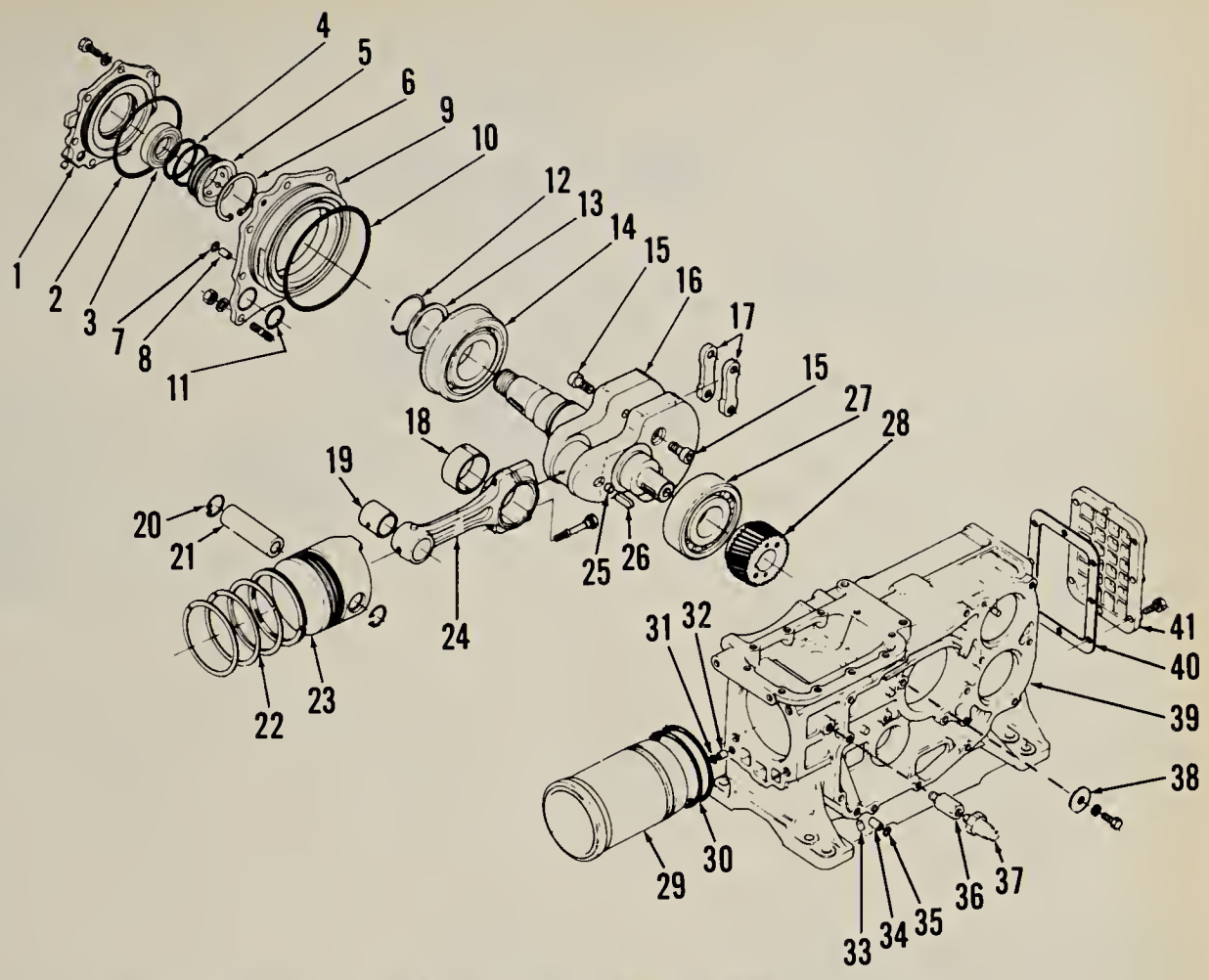


Fig. K1-22—Exploded view of crankshaft, piston, rod and block assemblies.

retainer (14–Fig. K1-21) and extract balancer shafts (9). Inspect shafts, gears and bearings and renew if damaged. When reinstalling balancer assemblies, refer to GEAR TRAIN section for proper timing of balancer gears.

PISTON AND ROD UNIT

REMOVE AND REINSTALL. Piston and connecting rod are removed as a unit after removing cylinder head, crankcase cover (41–Fig. K1-22) and balancer shafts (9–Fig. K1-21). Unscrew rod cap retaining screws, detach rod cap and extract piston and rod from head end of engine.

When assembling piston and rod, arrow on original equipment piston crown should be on same side as rod and cap alignment marks as shown in Fig. K1-23). Install piston and rod in engine so piston arrow (A) points towards engine top. Replacement piston does not have arrow on crown and may be installed in either direction. Install rod cap so marks (M) on rod and cap are aligned and tighten rod screws to 30-34 N·m (22-25 ft.-lbs.) on EA400-N, EA400-NB, EA450-N and EA450-NB or to 49-54 N·m (36-40 ft.-lbs.) on all other models.

PISTON, RINGS AND SLEEVE

All models are equipped with an aluminum piston which uses three compression rings and an oil control ring. Piston and rings are available in standard size only.

Piston pin boss inner diameter should be 25.00-25.013 mm (0.9843-0.9847 inch) on Models EA400-N, EA400-NB, EA450-N and EA450-NB. Renew piston if diameter exceeds 25.04 mm (0.986 inch). On all other models, pin boss inner diameter should be 27.000-27.021 inch (1.0630-1.0638 inches) and maximum allowable diameter is 27.04 mm (1.0646 inches).

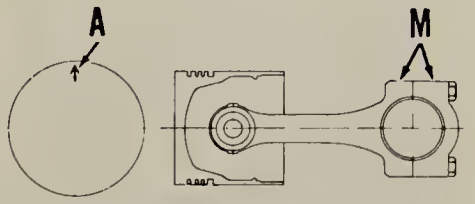


Fig. K1-23—Assemble rod, cap and piston so marks (M) on rod and cap are on same side as piston arrow (A). Install in engine so marks (M) and arrow (A) are up.

Desired piston ring end gap is 0.2-0.4 mm (0.008-0.016 inch) for all rings. Side clearance of compression rings in piston grooves should be 0.04-0.07 mm (0.0016-0.0027 inch) and oil ring side clearance should be 0.02-0.05 mm (0.0008-0.0020 inch).

Cylinder sleeve inside diameter should be 78.000-78.019 mm (3.0709-3.0716 inches) on Models EA400-N and EA400-NB, 84.000-84.022 mm (3.3071-3.3080 inches) on Models EA450-N and EA450-NB, 86.000-86.022 mm (3.3858-3.3867 inches) on Models EA500-N and EA500-

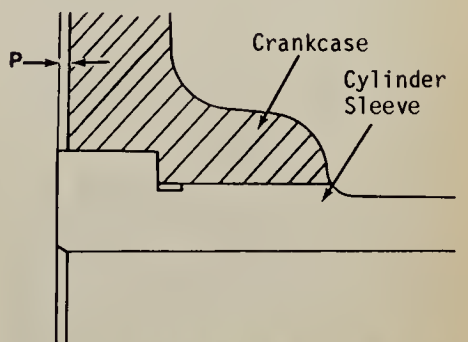


Fig. K1-24—Use a straightedge and feeler gage to measure cylinder sleeve protrusion beyond crankcase surface. Refer to text.

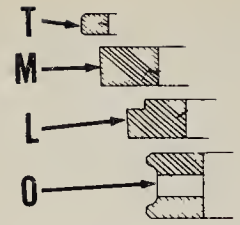


Fig. K1-25—View of ring configuration for top compression ring (T), middle compression ring (M), lower compression ring (L) and oil control ring (O).

NB or 92.000-92.022 mm (3.6220-3.6229 inches) on Models EA600-N and EA600-NB. Renew cylinder sleeve if wear exceeds 0.20 mm (0.008 inch). With sleeve installed in crankcase, measure protrusion (P–Fig. K1-24) of sleeve beyond crankcase surface using a straightedge and feeler gage. Desired sleeve protrusion is 0.08-0.18 mm (0.003-0.007 inch). Renew sleeve if protrusion is not within recommended limits.

When installing rings onto piston, note shape and location of rings as shown in Fig. K1-25. Stagger ring end gaps evenly around piston.

PISTON PIN

A full floating piston pin is used on all models. Piston pin outside diameter is 25.002-25.011 mm (0.9843-0.9847 inch) on Models EA400-N, EA400-NB, EA450-N and EA450-NB. On all other models, pin diameter is 27.002-27.011 mm (1.0630-1.0634 inches). Clearance between pin and connecting rod bushing should be 0.014-0.038 mm (0.0006-0.0015 inch) with a maximum allowable clearance of 0.20 mm (0.008 inch).

CONNECTING ROD AND BEARINGS

The connecting rod is equipped with a renewable bushing in the small end and insert type bearings in the big end. Inner diameter of standard size big end bearing should be 44.010-44.056 mm (1.7327-1.7345 inches) for Models EA400-N, EA400-NB, EA450-N and EA450-NB, or 48.010-48.056 mm (1.8902-1.8920 inches for all other models. Clearance between bearing and crankpin should be 0.035-0.097 mm (0.0014-0.0038 inch) for all models. Bearings are available in 0.25 and 0.50 mm undersizes.

Inner diameter of small end bushing is 25.025-25.040 mm (0.9852-0.9858 inch) for Models EA400-N, EA400-NB, EA450-N and EA450-NB, or 27.025-27.040 mm (1.0640-1.0646 inches) for all other models. Clearance between bushing and piston pin should be 0.014-0.038 mm (0.0006-0.0015 inch) for all models.

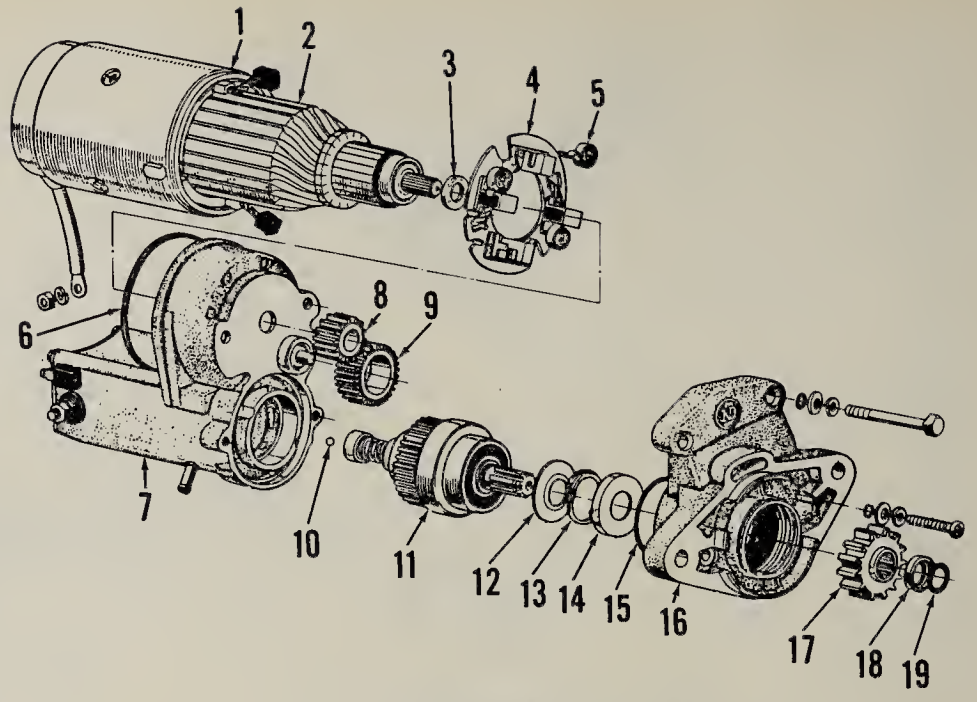


Fig. K1-26—Exploded view of electric starter.

1. Frame
2. Armature
3. Felt washer
4. Brush assy.
5. Brush spring
6. Gasket
7. Switch housing assy.
8. Gear
9. Gear
10. Ball
11. Drive assy.
12. Thrust washer
13. Spring
14. Spring holder
15. "O" ring
16. End frame
17. Gear
18. Collar
19. Retainer

CAMSHAFT

The camshaft is supported by a ball bearing at the gear end while the opposite end rides directly in the cylinder block.

R&R AND OVERHAUL. To remove camshaft, remove cylinder head and push rods. Remove gearcase (31–Fig. K1-16), then unscrew bearing retainer (6). Rotate camshaft one turn to force tappets away from lobes and withdraw camshaft while being careful not to dislodge tappets.

Camshaft lobe height for intake and exhaust lobes is 27 mm (1.0630 inches) with a wear limit of 26.5 mm (1.0433 inches) for Models EA400-N, EA400-NB, EA450-N and EA450-NB, or 33.5 mm (1.3189 inches) with a wear limit of 33 mm (1.2992 inches) for all other models.

Diameter of plain bearing end of camshaft is 21.967-21.980 mm (0.8648-0.8654 inch) while bearing bore in crankcase is 22.000-22.021 mm (0.8661-0.8670 inch). Desired clearance is 0.02-0.054 mm (0.0008-0.0021 inch) while maximum allowable clearance is 0.25 mm (0.010 inch).

Refer to GEAR TRAIN section when installing camshaft for proper alignment of gear timing marks. Check backlash between camshaft and crankshaft gears. Backlash should be 0.048-0.14 mm (0.0019-0.0055 inch) for all models. Gear must be renewed if backlash exceeds 0.3 mm (0.012 inch).

CRANKSHAFT AND BEARINGS

R&R AND OVERHAUL. To remove crankshaft, remove flywheel, balancer shafts and piston with rod as previously outlined. Remove seal housing (1–Fig. K1-22) and unscrew bearing carrier (9) retaining nuts, then withdraw crankshaft and bearing assembly from crankcase. Disassemble as required.

When inspecting components, be sure oil sleeve (5) is clean and serviceable as pressurized oil is directed through sleeve from oil passage in seal housing (1) to crankshaft for rod bearing lubrication. Inner diameter of sleeve should be 48.000-48.025 mm (1.8898-1.8907 inches) while corresponding diameter of crankshaft should be 47.959-47.975 mm (1.8881-1.8888 inches). Maximum allowable clearance between sleeve and crankshaft is 0.15 mm (0.006 inch). Be sure "O" rings (4) seal effectively or low pressure may result.

Note balancer weights (17) attached to crankshaft on Models EA400-N, EA400-NB, EA450-N and EA450-NB.

Crankshaft crankpin diameter is 43.959-43.975 mm (1.7307-1.7313 inch-

es) for Models EA400-N, EA400-NB, EA450-N and EA450-NB, or 47.959-47.975 mm (1.8881-1.8888 inches) for all other models. Maximum allowable clearance between crankpin and bearing is 0.25 mm (0.010 inch). Rod bearings are available in standard size and 0.25 and 0.50 mm undersizes.

Crankshaft end play should be 0.05-0.46 mm (0.002-0.018 inch). Renew main bearing retainer washer (13) if end play is not within specified limits.

Refer to GEAR TRAIN section for proper timing of crankshaft gear.

ALTERNATOR

Models EA400-NB, EA450-NB, EA500-NB and EA600-NB are equipped with an alternator mounted behind the fan. The fan serves as the alternator rotor. Alternator output should be 8 volts with 3.1 amperes current at alternator speed of 6800 rpm.

ELECTRIC STARTER

Models EA400-NB, EA450-NB, EA500-NB and EA600-NB are equipped with an electric starter as shown in Fig. K1-26. Minimum brush length is 10 mm (0.394 inch) while wear limit of commutator is 29 mm (1.141 inches) diameter. With no load imposed on starter and using an 11.5 volt source, the starter shaft should rotate at 3500 rpm or more while drawing less than 90 amperes current.

KUBOTA

Model	No. Cyls.	Bore	Stroke	Displ.
D650-B	3	64 mm (2.520 in.)	70 mm (2.756 in.)	675 cc (41.2 cu. in.)
D750-B	3	68 mm (2.677 in.)	70 mm (2.756 in.)	762 cc (46.5 cu. in.)
D850-B	3	72 mm (2.835 in.)	70 mm (2.756 in.)	855 cc (52.2 cu. in.)
DH850-B	3	72 mm (2.835 in.)	70 mm (2.756 in.)	855 cc (52.2 cu. in.)
D950-B	3	75 mm (2.953 in.)	70 mm (2.756 in.)	927 cc (56.5 cu. in.)
Z500-B	2	68 mm (2.677 in.)	70 mm (2.756 in.)	508 cc (31.0 cu. in.)
Z600-B	2	72 mm (2.835 in.)	70 mm (2.756 in.)	570 cc (34.8 cu. in.)
ZB500C-B	2	68 mm (2.677 in.)	70 mm (2.756 in.)	508 cc (31.0 cu. in.)
ZB600C-B	2	72 mm (2.835 in.)	70 mm (2.756 in.)	570 cc (34.8 cu. in.)

All engines in this section are liquid-cooled four-stroke diesel engines. Crankshaft rotation is counterclockwise viewed from flywheel end. Firing order is 1-2-3 for three-cylinder models.

MAINTENANCE

LUBRICATION

Recommended crankcase oil is SAE 10W for ambient oil temperatures of 0°C (32°F) and below, SAE 20 for temperatures of 0°-25°C (32°-77°F) and SAE 30 for temperatures above 25°C (77°F). SAE 10W-30 oil may be substituted for recommended straight weight oils for use in all temperatures. Use oil with API classification CC/CD. Crankcase capacity is 4.6 liters (4.8 quarts) for Models D650-B, D750-B, D850-B and D950-B, 3.7 liters (3.9 quarts) for Models DH850-B, 2.6 liters (2.7 quarts) for Models Z500-B and Z600-B or 3.1 liters (3.3 quarts) for Models ZB500C-B and ZB600C-B. Manufacturer recommends renewing engine oil and oil filter after every 150 hours of operation.

All models are equipped with a pressure lubrication system. Oil is directed from the oil pump to the oil pressure relief valve and oil filter. Oil is routed through an oil passage in the cylinder block to the main bearings, then through crankshaft oil passages to the crankpins. The cylinder block oil passage also routes oil to the cylinder head to lubricate the valve train.

Normal oil pressure is 295-440 kPa (43-64 psi) with engine at operating speed and temperature. Minimum allowable pressure is 196 kPa (28 psi). Refer to OIL PUMP section for pump service.

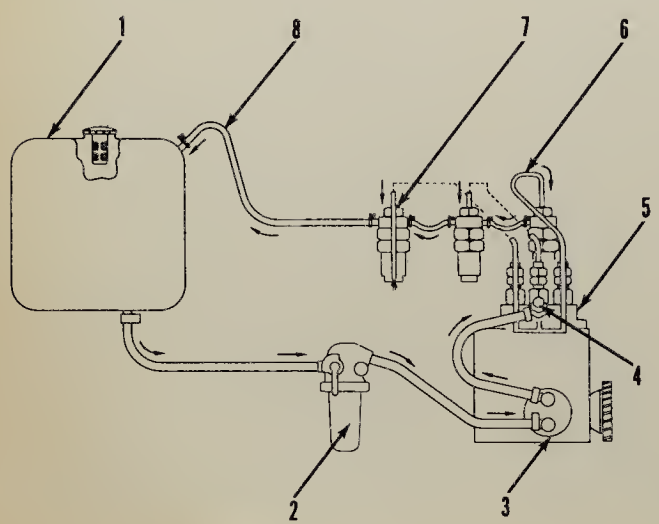


Fig. K2-1—Drawing of typical fuel system.
1. Fuel tank
2. Filter assy.
3. Fuel pump
4. Bleed screw
5. Injection pump
6. High pressure line
7. Injector
8. Fuel return line

FUEL SYSTEM

FUEL FILTER. A combination of fuel shut-off valve and filter assembly (2--Fig. K2-1) is attached to engine. Fuel filter element is renewable and manufacturer recommends renewing filter after every 400 hours of operation. However, if engine indicates signs of fuel starvation (loss of power or surging), renew filter regardless of hours of operation. After renewing filter, air must be bled from system as outlined in the following paragraph.

BLEED FUEL SYSTEM. To bleed air from fuel system, first loosen injection pump bleed screw (4--Fig. K2-1) and open fuel shut-off valve. With engine stop lever in STOP position, rotate crankshaft with starter or manually to operate fuel transfer pump (3). When air-free fuel flows from bleed screw, retighten bleed screw.

If engine fails to start at this point, loosen high pressure line (6) fittings at

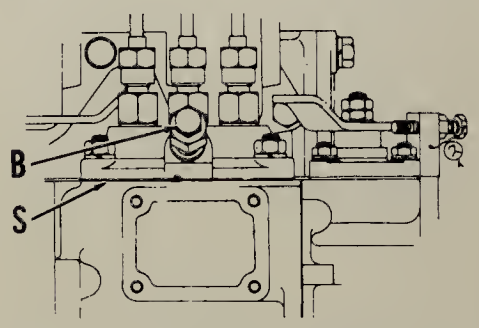


Fig. K2-2—Injection timing is adjusted by adding or deleting shims (S) between pump and engine block. Air may be bled from injection pump by loosening bleed screw (B).

injectors. With engine stop lever in RUN position, crank engine to operate injection pump. Retighten injector line fittings when fuel is discharged from injector lines, then start engine.

INJECTION PUMP TIMING. Injection pump timing is adjusted using shims (S – Fig. K2-2). To check injection pump timing proceed as follows: Disconnect high pressure line for number 1 cylinder from injection pump, then unscrew delivery valve holder (1 – Fig. K2-3) and remove valve spring (3) and delivery valve assembly (5). Reinstall delivery valve holder (1) and connect a suitable spill pipe to valve holder. Aim spill pipe at a receptacle to catch discharged fuel. Move throttle control to full open position. Rotate engine flywheel slowly in counterclockwise direction until fuel just stops flowing from spill pipe. Beginning of injection occurs at this point. If timing is correct, "F1" mark (Fig. K2-4) on flywheel should be aligned with timing mark (M) on cylinder block rear plate.

To adjust injection timing, remove injection pump and add shim gaskets to retard timing or remove shims to advance timing. Each shim alters timing approximately 1½ crankshaft degrees.

When reinstalling injection pump, be sure pump control rack pin properly engages governor operating fork. Tighten pump mounting nuts or screws to 24-27 N·m (18-20 ft.-lbs.). Reinstall delivery valve and spring and tighten delivery valve holder to 40-49 N·m (30-36 ft.-lbs.). Bleed air from system as previously outlined.

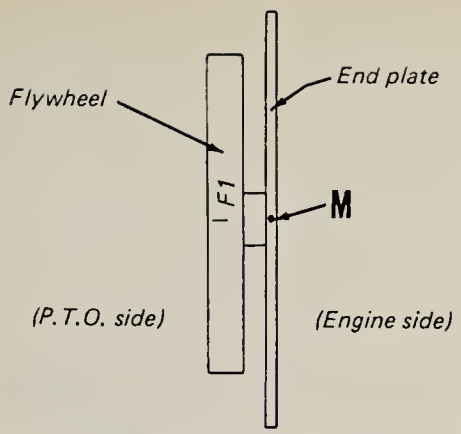


Fig. K2-4—View of "F1" injection timing mark on flywheel and timing mark (M) on end plate of models so equipped. Refer to text.

GOVERNOR

All models are equipped with a flyball type governor mounted on front end of fuel injection pump camshaft. Refer to Fig. K2-5 for an exploded view of governor linkage.

Slow idle speed for all models 800 rpm and is adjusted by turning speed screw (37 – Fig. K2-5). High idle speed and maximum fuel limiting stop screws are sealed and should be adjusted by qualified personnel only. High idle (no-load) speed should be 3780 rpm for Model DH850-B, 3500 rpm for Models Z600-B, ZB600C-B or 3200 rpm for all other models. Turn high idle speed screw (40) for adjustment.

Maximum fuel limiting stop should be set to prevent excessive smoke level at slight overload. To make adjustment, remove seal cap, loosen jam nut and turn adjuster (19) in to lower smoke level or out to raise smoke level.

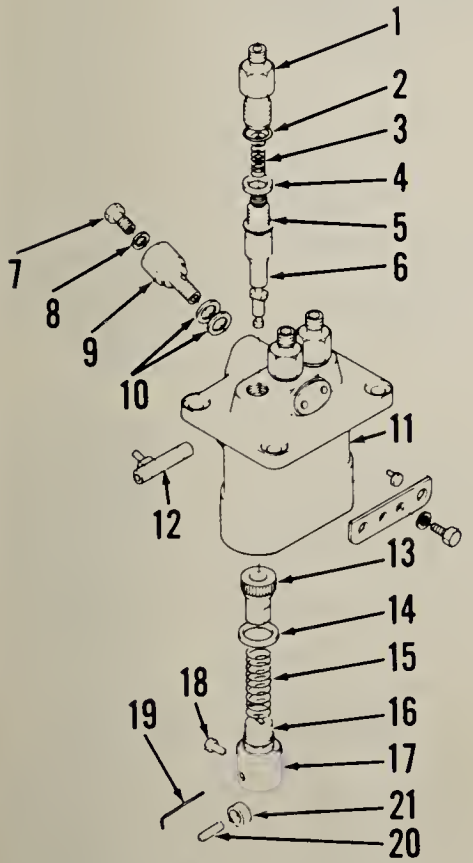


Fig. K2-3—Exploded view of fuel injection pump.

1. Delivery valve holder
2. "O" ring
3. Spring
4. Shim
5. Delivery valve assy.
6. Plunger
7. Air bleed screw
8. Gasket
9. Adapter
10. Gaskets
11. Pump body
12. Control rack
13. Control sleeve
14. Washer
15. Spring
16. Spring seat
17. Tappet
18. Guide pin
19. Pin
20. Pin
21. Roller

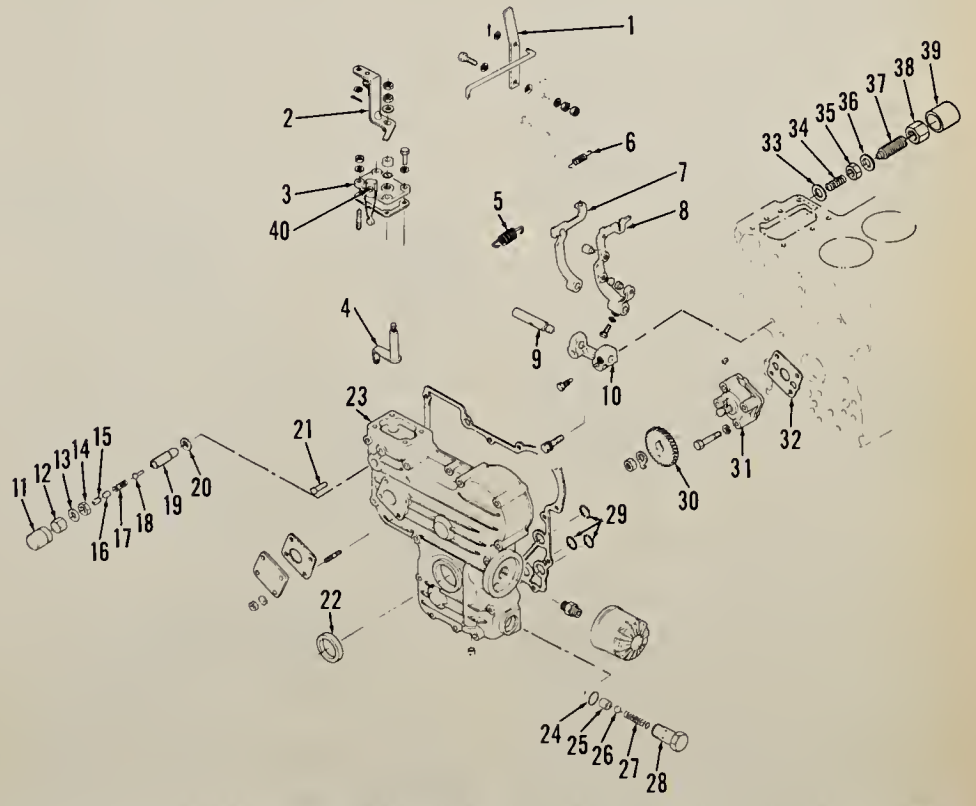
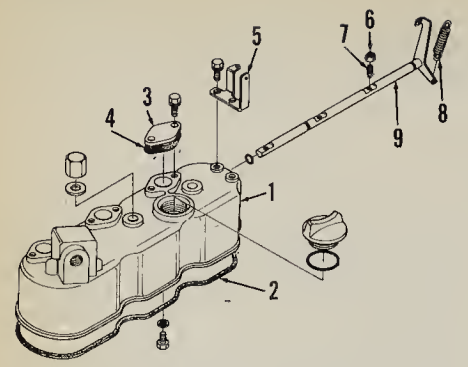


Fig. K2-5—Exploded view of timing gear cover and associated components. Be sure "O" rings (29) are in place when installing cover (23).

1. Speed control
2. Control lever
3. Plate
4. Control arm
5. Governor spring
6. Start spring
7. Governor arm
8. Pump control arm
9. Pivot pin
10. Pivot block
11. Cap
12. Cap nut
13. Gasket
14. Locknut
15. Maximum fuel limiting screw
16. Spacer
17. Spring
18. Pin
19. Maximum fuel limiting body
20. Gasket
21. Start spring pin
22. Seal
23. Timing gear cover
24. "O" ring
25. Oil pressure relief valve seat
26. Relief valve ball
27. Spring
28. Valve body
29. "O" rings
30. Pump gear
31. Oil pump
32. Gasket
33. Gasket
34. Spring
35. Locknut
36. Gasket
37. Low idle speed screw
38. Cap nut
39. Cap
40. High idle speed screw



K2-6—View of valve cover and compression release components.

1. Valve cover
2. Gasket
3. Cover
4. Gasket
5. Bracket
6. Locknut
7. Compression release screw
8. Spring
9. Compression release shaft

COMPRESSION RELEASE

All models are equipped with a compression release which holds exhaust valves open slightly when compression release lever (9—Fig. K2-6) is rotated. To adjust compression release, rotate engine crankshaft so piston in cylinder being adjusted is at top dead center on compression. Remove cover (3), loosen locknut (6) and back out adjusting screw (7). Rotate compression release lever to engaged position. Turn adjusting screw (7) in until it contacts exhaust rocker arm, then turn screw an additional 1½ turns. Tighten locknut and adjust remaining cylinders. Check operation of compression release being sure exhaust valves do not contact pistons.

AIR FILTER

All models are equipped with a dry type renewable air filter. Manufacturer recommends blowing out filter after every 100 to 200 hours of operation and renewing filter after six cleanings or one year.

COOLING SYSTEM

All engines are liquid-cooled. Some early models used a thermo-siphon system (without water pump) to circulate coolant, while late models are equipped with forced coolant circulation provided by a centrifugal water pump. On all models, radiator pressure rating is 88 kPa (13 psi).

Cooling system should be drained and refilled after every 500 hours of operation or once a year. It is recommended that a mixture of water and ethylene glycol antifreeze be used even if temperatures below freezing are not expected. The antifreeze solution contains additives which help prevent corrosion of cooling system components.

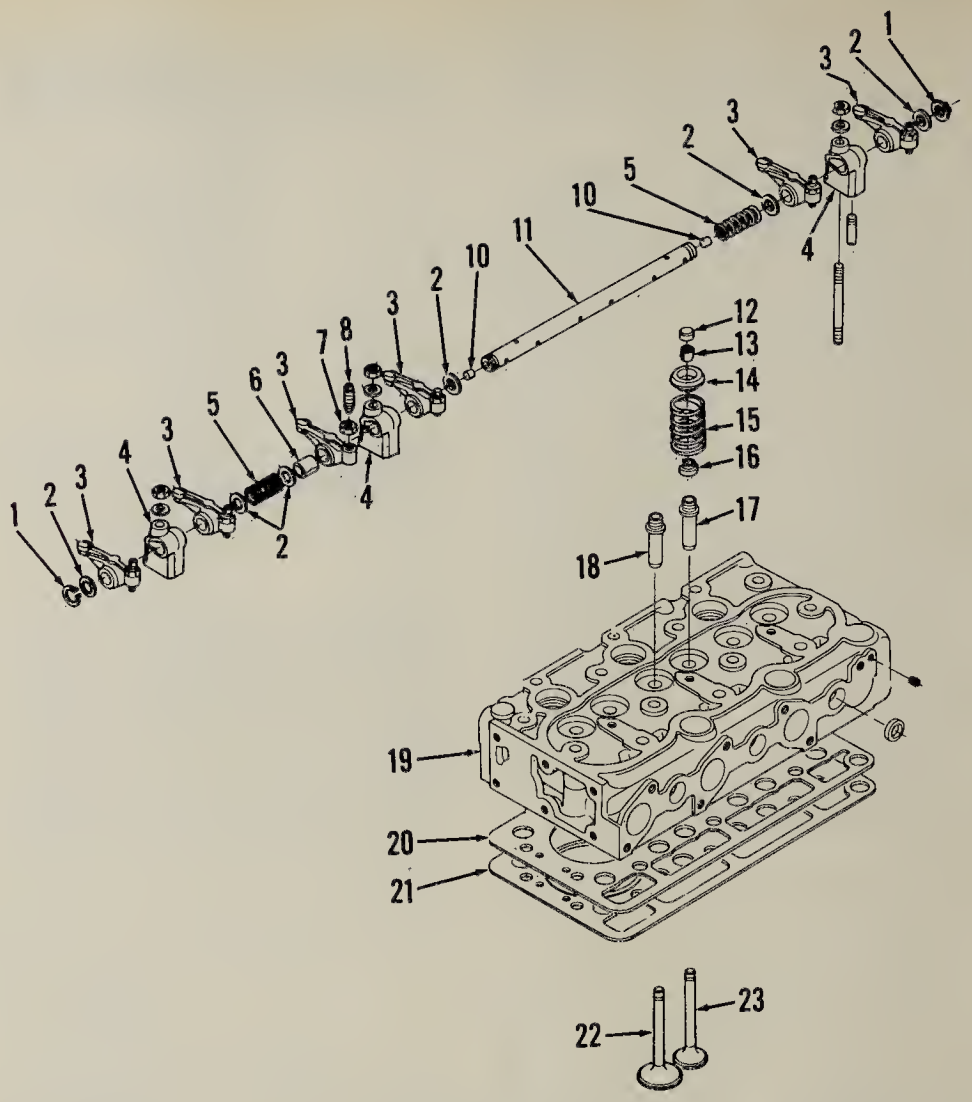


Fig. K2-7—Exploded view of valve train.

1. Snap ring
2. Washer
3. Rocker arm
4. Shaft stand
5. Spring
6. Bushing
7. Locknut
8. Adjusting screw
10. Set screw
11. Rocker shaft
12. Valve cap
13. Retainer keys
14. Retainer
15. Spring
16. Seal
17. Exhaust valve guide
18. Intake valve guide
19. Cylinder head
20. Shim
21. Gasket
22. Intake valve
23. Exhaust valve

Fan belt tension is correct if a pressure of 59-68 N (13-15 pounds) applied against belt at midpoint between crankshaft pulley and alternator pulley deflects belt approximately 8 mm (5/16 inch).

REPAIRS

TIGHTENING TORQUES

Refer to the following table for special tightening torques.

Connecting rod	27-30 N·m (20-22 ft.-lbs.)
Crankshaft pulley nut	138-157 N·m (102-115 ft.-lbs.)
Crankshaft seal carrier	10-12 N·m (8-9 ft.-lbs.)
Cylinder head	57-61 N·m (42-45 ft.-lbs.)
Flywheel	54-59 N·m (40-43 ft.-lbs.)
Injection pump	24-27 N·m (18-20 ft.-lbs.)
Injector nozzle nut	30-49 N·m (22-36 ft.-lbs.)
Main bearing retainer	30-34 N·m (22-25 ft.-lbs.)
Rocker arm brackets	17-20 N·m (13-15 ft.-lbs.)

COMPRESSION PRESSURE

Compression pressure should be checked with all injectors removed while cranking engine with starter at 200 to 300 rpm. Compression pressure should be 2667-3138 kPa (387-455 psi) for Models D650-B, D750-B, Z500-B and ZB500C-B; 2746-3236 kPa (398-469 psi) for Models D850-B, DH850-B, Z600-B and ZB600C-B; or 2550-2942 kPa (370-427 psi) for Model D950-B. Difference in compression pressure among cylinders should not exceed 10 percent.

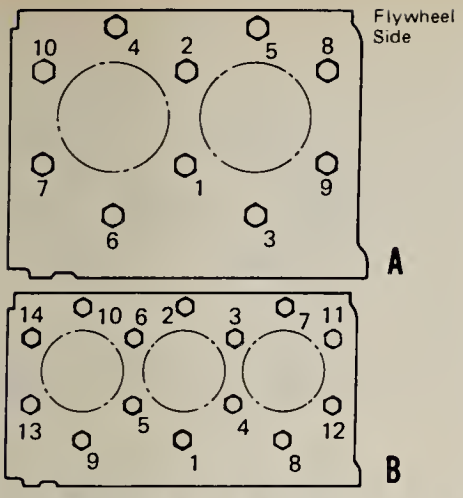


Fig. K2-8—Follow sequence in diagram A when tightening cylinder head fasteners on two-cylinder models or diagram B on three-cylinder models.

VALVE CLEARANCE

Valve clearance should be adjusted with engine cold and piston at top dead center on compression. Remove rocker cover, then turn rocker arm adjusting screw until a feeler gage of appropriate thickness can be inserted between rocker arm and end of valve. Recommended clearance is 0.145-0.185 mm (0.006-0.007 inch) for both intake and exhaust.

Repeat procedure for remaining cylinders. On two-cylinder engines, rotate crankshaft one complete revolution (360°) to position second piston at TDC on compression. On three-cylinder engines, rotating crankshaft ⅔ turn (240°) will place the next piston in firing order (1-2-3) at TDC on compression.

CYLINDER HEAD

R&R AND OVERHAUL. Drain coolant and detach radiator hose. Remove rocker arm cover, injector fuel lines and injectors. Remove fan belt. Remove rocker arm shaft assembly and push rods. Unscrew cylinder head retaining bolts and remove head, gasket and shim (if equipped).

Check flatness of head surface using a straightedge placed along mounting surface of head. If a 0.05 mm (0.002 inch) feeler gage will pass under straightedge, cylinder must be resurfaced. If head is resurfaced, check piston-to-head clearance as outlined in following paragraph.

To check piston-to-head clearance, install head and gasket with valves and springs installed but with injectors removed. Tighten head bolts to specified torque following appropriate tightening sequence shown in Fig. K2-8. Insert a suitable measuring gage, such as soft solder or lead wire, through injector hole. Be sure wire does not go between valve seat and an open valve. Rotate crankshaft to move piston through top dead center position, then withdraw and measure gage wire thickness. Clearance between piston and cylinder head should be 0.6-0.8 mm (0.024-0.031 inch). Clearance may be increased by installing a shim gasket (20–Fig. K2-7) between cylinder head and head gasket (21).

Reverse removal procedure to reinstall cylinder head. Be sure cylinder head and crankcase mounting surfaces are clean. Do not apply any sealing compounds to gasket surface. Lubricate threads of cylinder head bolts with clean engine oil. Tighten cylinder head bolts and rocker arm bracket nuts to specified torques as listed in TIGHTENING TORQUES paragraph. Tighten head bolts evenly in steps following appropriate sequence shown in Fig. K2-8. Adjust valve clearance as previously outlined. Operate engine for 30 minutes, then retorque cylinder head bolts and readjust valve clearance.

VALVE SYSTEM

Intake and exhaust valves seat directly in cylinder head. Valve face and seat angles are 45 degrees. Desired valve seat width is 2.1 mm (0.083 inch). After refacing valves and seats, check distance valve head is recessed from cylinder head surface. Valve should be recessed 0.9-1.1 mm (0.035-0.043 inch). If recession exceeds 1.3 mm (0.051 inch), a shim washer of appropriate thickness should be added between valve springs and cylinder head to maintain correct valve spring tension and cylinder head surface should be machined to obtain recommended recession.

Valve stem diameter should be 6.960-6.975 mm (0.2740-0.2765 inch) for intake and exhaust. Inside diameter of valve guides should be 7.010-7.025 mm (0.2759-0.2765 inch). Recommended clearance between valve stems and guides is 0.035-0.065 mm (0.0014-0.0026 inch) and maximum allowable clearance is 0.1 mm (0.004 inch). When renewing guides, note that intake and exhaust guides are not interchangeable. After installation, check guide inside diameter and ream to provide recommended clearance.

Intake and exhaust valve springs are identical. Valve spring free length should be 35.1-35.6 mm (1.382-1.402 inches) while installed height is 31 mm (1.220 inches). Spring pressure at installed height should be 74 N (16.6 pounds) with a minimum allowable pressure of 63 N (14.1 pounds). Renew spring if distorted or otherwise damaged.

Rocker arm bushings (6–Fig. K2-7) are renewable. Bushing ID should be 10.997-11.038 mm (0.4330-0.4346 inch). Rocker shaft diameter should be 10.973-10.984 mm (0.4320-0.4324 inch). Desired clearance between rocker arm shaft and bushings is 0.013-0.065 mm (0.0005-0.0026 inch) while maximum allowable clearance is 0.15 mm (0.006 inch). When renewing rocker arm bushings, make certain the oil hole in bushing is aligned with hole in rocker arm.

INJECTOR

WARNING: Fuel emerges from injector with sufficient force to penetrate the skin. When testing injector, keep yourself clear of nozzle spray.

REMOVE AND REINSTALL. Before removing an injector, or loosening injector lines, thoroughly clean injector, lines and surrounding area using compressed air and a suitable solvent.

To remove injector unit, first remove high pressure line leading from injection pump to injector. Disconnect bleed line by removing nut and banjo fitting, or by pulling line(s) from banjo nipple fitting (2–Fig. K2-9). With pressure and bleed-back lines removed, unscrew injector from its mounting position on cylinder head. Note that a special nozzle holder socket wrench, Code No. 07916-30841, is available from manufacturer for use in removing and installing injectors.

When installing injector, make sure that machined seating surface in cylinder head is completely clean and free from carbon buildup. Use a new copper washer underneath injector nozzle and tighten injector carefully to 29-49 N·m (22-36 ft.-lbs.).

TESTING. A complete job of testing and adjusting the injector requires use of special test equipment. Only clean, approved testing oil should be used in tester tank. Nozzle should be tested for opening pressure, seat leakage and spray pattern. When tested, nozzle should open with high-pitched buzzing sound, and cut-off quickly at end of injection with a minimum of seat leakage.

Before conducting test, operate tester lever until fuel flows, then attach injector. Close valve to tester gage and pump tester lever a few quick strokes to be sure nozzle valve is not stuck, and that possibilities are good that injector can be returned to service without disassembly.

OPENING PRESSURE. Open valve to tester gage, then operate tester lever slowly while observing gage reading. Opening pressure should be 13720-14710 kPa (1990-2133 psi).

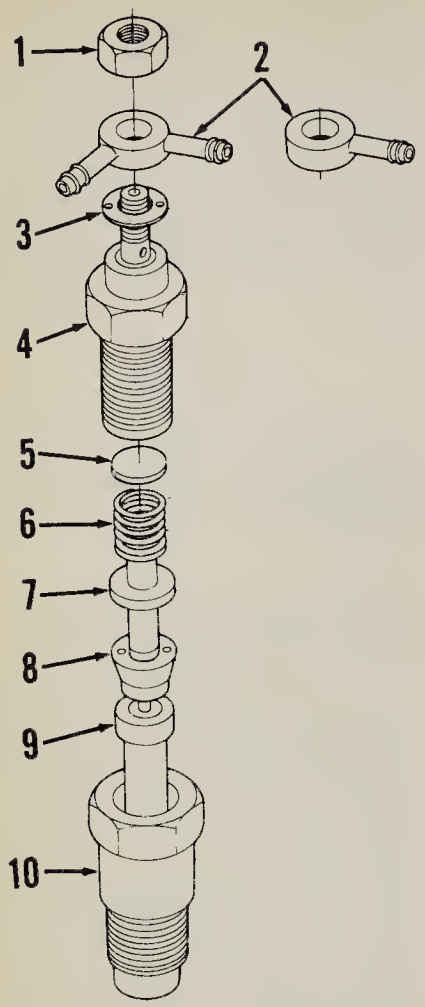


Fig. K2-9—Exploded view of injector.

1. Nut
2. Bypass fitting
3. Washer
4. Pressure fitting
5. Shim
6. Spring
7. Pressure pin
8. Spacer
9. Nozzle & valve
10. Nozzle nut

Opening pressure is adjusted by adding or removing shims (5–Fig. K2-9). Adding or removing one 0.1 mm (0.004 inch) shim will change opening pressure approximately 980 kPa (140 psi).

SEAT LEAKAGE. Operate tester lever slowly to maintain pressure at 1000 kPa (150 psi) below nozzle opening pressure and observe nozzle tip for leakage. If a drop forms within a period of 10 seconds, nozzle valve is not seating and must be overhauled or renewed.

SPRAY PATTERN. Spray pattern should be well atomized and slightly conical, emerging in a straight axis from nozzle tip. If pattern is wet, ragged or intermittent, nozzle must be overhauled or renewed.

OVERHAUL. Hard or sharp tools, emery cloth, grinding compound or other than approved solvents or lapping compounds must never be used. An approved nozzle cleaning kit is available through a number of specialized sources.

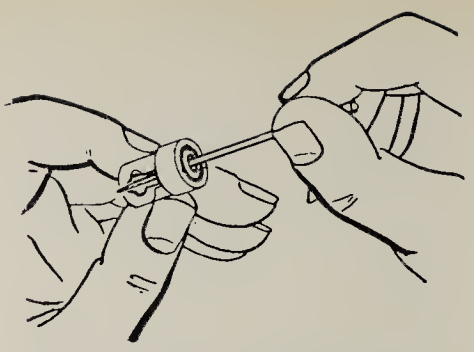


Fig. K2-10—Use a pointed hardwood stick to clean spray hole as shown.

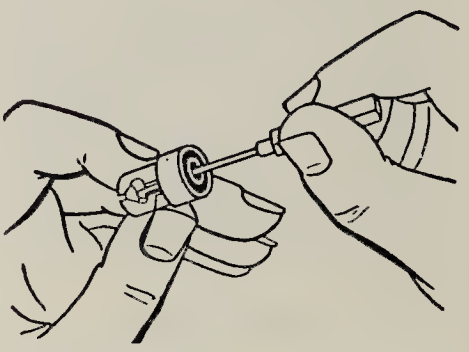


Fig. K2-11—Use hooked scraper to clean carbon from pressure chamber.

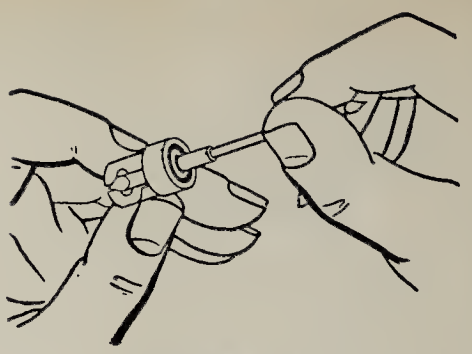


Fig. K2-12—Clean valve seat using brass scraper as shown.

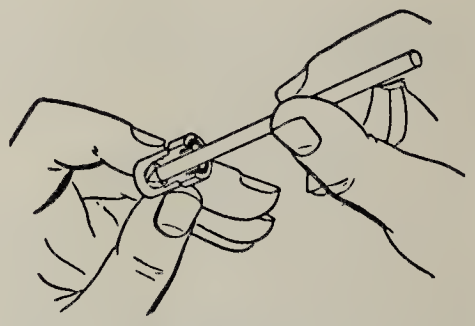


Fig. K2-13—Polish seat using polishing stick and mutton tallow.

Wipe all dirt and loose carbon from exterior of nozzle and holder assembly. Refer to Fig. K2-9 for exploded view and proceed as follows:

Secure pressure fitting (4) in a soft-jawed vise or holding fixture and remove nozzle nut (10). Place all parts in clean calibrating oil or diesel fuel as they are removed, using a compartmented pan and using extra care to keep parts from each injector together and separate from other units.

Clean exterior surfaces with a brass wire brush. Soak parts in an approved carbon solvent, if necessary, to loosen hard carbon deposits. Rinse parts in clean diesel fuel or calibrating oil immediately after cleaning to neutralize the solvent and prevent etching of polished surfaces.

Clean nozzle spray hole from inside using a pointed hardwood stick or wood splinter as shown in Fig. K2-10. Scrape carbon from pressure chamber using hooked scraper as shown in Fig. K2-11. Clean valve seat using brass scraper as shown in K2-12, then polish seat using wood polishing stick and mutton tallow as in Fig. K2-13.

Back flush nozzle using reverse flusher adapter. Reclean all parts by rinsing thoroughly in clean diesel fuel or calibrating oil and assemble while parts are immersed in clean fluid. Make sure adjusting shim pack is intact. Tighten nozzle retaining nut (10–Fig. K2-9) to a torque of 59-78 N·m (44-57 ft.-lbs.). Do not overtighten as distortion may cause valve to stick, and no amount of overtightening can stop a leak caused by scratches or dirt. Retest assembled injector as previously outlined.

GLOW PLUGS

Glow plugs are parallel connected with each individual glow plug grounding through its mounting threads. Indicator light should glow after about 30 seconds if units are operating satisfactorily.

If indicator light fails to glow, check for an open circuit at switch, indicator lamp or glow plug connections. Using an ohmmeter, check resistance of each glow plug in turn. Resistance between glow plug terminal and body should be about 1.6 ohms. If resistance is zero, glow plug is shorted. If resistance is infinite, glow plug element is broken.

INJECTION PUMP

All models are equipped with an injection pump similar to type shown in Fig. K2-3. The injection pump should be tested and overhauled by a shop qualified in diesel injection pump repair.

The injection pump tappets are actuated by lobes on injection pump camshaft (12–Fig. K2-17). Inspect camshaft each time injection pump is removed.

Tighten pump retaining nuts to 24-27 N·m (18-20 ft.-lbs.) and refer to INJECTION PUMP TIMING section.

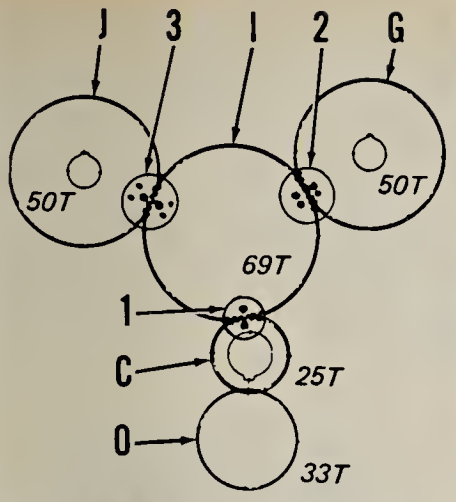


Fig. K2-14—Diagram of drive gears showing proper alignment of timing marks. Note three marks (3) on injection pump gear (J) and idler gear (I); two marks (2) on camshaft gear (G) and idler gear (I); single marks on crankshaft gear (C) and idler gear (I). No marks are used on oil pump gear (O).

TIMING GEARS AND COVER

To remove timing gear cover, first remove cover just below injection pump and detach governor spring (5–Fig. K2-5) from governor arm. Remove speed control plate (3) and governor spring. Disconnect start spring (6) from timing gearcase. Drain coolant and disconnect radiator hoses, then relocate radiator to provide clearance for crankshaft pulley removal. Remove fan belt and fan. Unscrew crankshaft pulley nut, then use a suitable puller to remove pulley. Unbolt and remove timing gear cover.

Backlash between any two gears should be 0.04-0.11 mm (0.002-0.004 inch). If backlash exceeds 0.2 mm (0.008 inch), renew gears as needed. Idler gear bushings (3–Fig. K2-19) and shaft (6) are renewable. When installing new idler gear bushings, press bushings in from each side of gear until flush with outer surfaces of gear. Tighten idler shaft mounting cap screws to 10-12 N·m (8-9 ft.-lbs.). If crankshaft gear is being renewed, heat new gear to about 100°C (212°F) before driving gear onto crankshaft.

Fig. K2-15—Measure clearance between inner and outer oil pump rotors as shown. Desired clearance is 0.11-0.15 mm (0.004-0.006 inch).

Fig. K2-16—Measure clearance between outer rotor and oil pump body as shown. Desired clearance is 0.07-0.15 mm (0.003-0.006 inch).

Refer to Fig. K2-14 for proper alignment of timing marks on crankshaft, idler, camshaft and injection pump camshaft gears. Renew crankshaft oil seal (22–Fig. K2-5) and lubricate seal lip with oil prior to reassembly. Be sure crankshaft oil slinger (13–Fig. K2-20), "O" ring (12) and sleeve (11) are properly located on crankshaft. Make certain the three "O" rings (29–Fig. K2-5) are in place. Tighten timing gear cover cap screws to 10-11 N·m (7-8 ft.-lbs.). Lubricate threads of crankshaft pulley nut with engine oil, then tighten nut to 138-157 N·m (102-115 ft.-lbs.).

OIL PUMP

R&R AND OVERHAUL. To remove oil pump, first remove timing gear cover as previously outlined. Use a suitable puller to remove pump drive gear.

Inspect pump rotors and body for wear or other damage. Clearance between inner and outer rotor, measured as shown in Fig. K2-15, should be 0.11-0.15 mm (0.004-0.006 inch) with an allowable limit of 0.2 mm (0.008 inch). Clearance between outer rotor and pump body, measured as shown in Fig. K2-16, should be 0.07-0.15 mm (0.003-0.006 inch) with an allowable limit of 0.25 mm (0.010 inch). Individual pump components are not available; pump must be serviced as a unit assembly.

Oil pressure relief ball (26–Fig. K2-5) and spring (27) are located in timing gear cover. Oil pressure should be 196-441 kPa (28-64 psi) and is not adjustable.

INJECTION PUMP CAMSHAFT

R&R AND OVERHAUL. To remove camshaft, first remove fuel injection pump and timing gear cover as outlined in previous paragraphs. Remove fuel transfer pump from side of crankcase. Remove cap screws securing governor arm pivot block (10–Fig. K2-5) and withdraw governor control arm assembly. Remove cap screws from camshaft retainer plate (9–Fig. K2-17, then withdraw camshaft (12), bearings and governor as an assembly. Remove snap ring (1), then separate gear (2) and governor assembly from camshaft being careful not to lose governor balls (3 and 5).

Inspect camshaft and bearings for excessive wear and other damage and renew if necessary.

To reinstall injection pump camshaft, reverse the removal procedure. Refer to TIMING GEARS AND COVER section to properly align timing marks during installation.

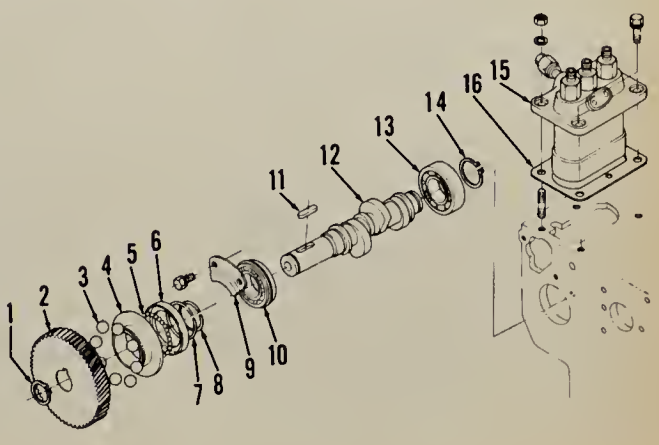
GOVERNOR

All models are equipped with a flyball type governor as shown in Fig. K2-17. Ball movement against governor sleeve (4) actuates governor lever (8–Fig. K2-5) which is connected to fuel injection control rack. Flyball movement is balanced by governor spring (5).

Governor components are accessible after removing timing gear cover. Inspect components and renew any which are excessively worn or damaged.

Fig. K2-17—Exploded view of injection pump camshaft and governor components.

1. Snap ring
2. Gear
3. Large governor balls (8)
4. Sleeve
5. Small governor balls (30)
6. Governor case
7. Retainer ring
8. Retainer ring
9. Bearing retainer
10. Bearing
11. Key
12. Injection pump camshaft
13. Bearing
14. Snap ring
15. Injection pump
16. Shim gasket



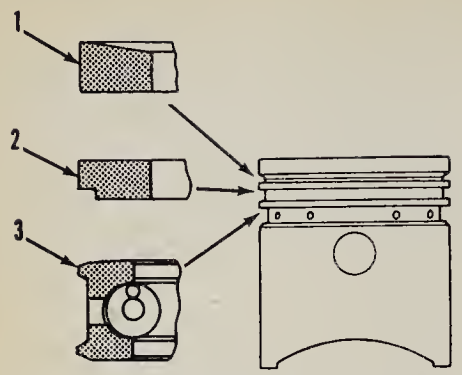


Fig. K2-18—Drawing showing correct installation of piston rings. Top ring (1) is keystone type and can be installed correctly only one way. Second compression ring (2) must be installed with notched edge downward. Oil control ring (3) may be installed either side up.

NOTE: There are 30 balls (5) 3.97 mm (0.156 inch) in diameter and eight balls (3) 13.44 mm (0.530 inch) in diameter contained in governor ball case.

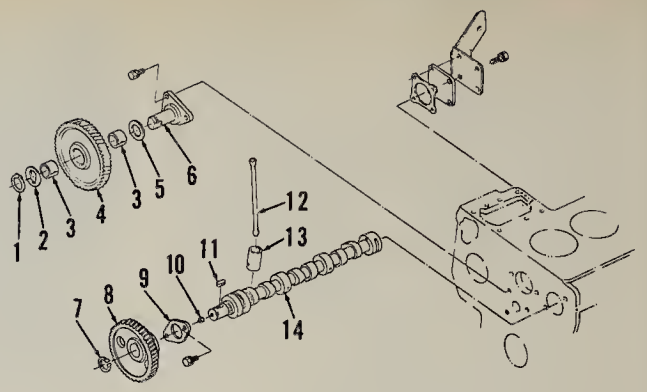
PISTON AND ROD UNITS

REMOVE AND REINSTALL. Piston and connecting rod are removed as a unit after removing oil pan, oil pickup and cylinder head. Be sure to remove carbon deposits and ring ridge (if present) from top of cylinder before attempting to remove piston. Unscrew rod cap retaining screws, detach rod cap and push piston and rod out top of crankcase. Identify piston and rod units and the cylinder from which they were removed so units can be reinstalled in their original locations.

Note that numbers are stamped on sides of rod and cap and should be on same side when assembled. Install piston and rod units so numbers on rod and cap are toward fuel injection pump side of engine. Lubricate threads of connecting rod cap screws with engine oil, then tighten to 27-30 N·m (20-22 ft.-lbs.).

Fig. K2-19—Exploded view of camshaft and idler gear assemblies.

1. Snap ring
2. Slotted washer
3. Bushing
4. Idler gear
5. Washer
6. Idler shaft
7. Snap ring
8. Gear
9. Retainer
10. Plug
11. Key
12. Push rod
13. Cam follower
14. Camshaft



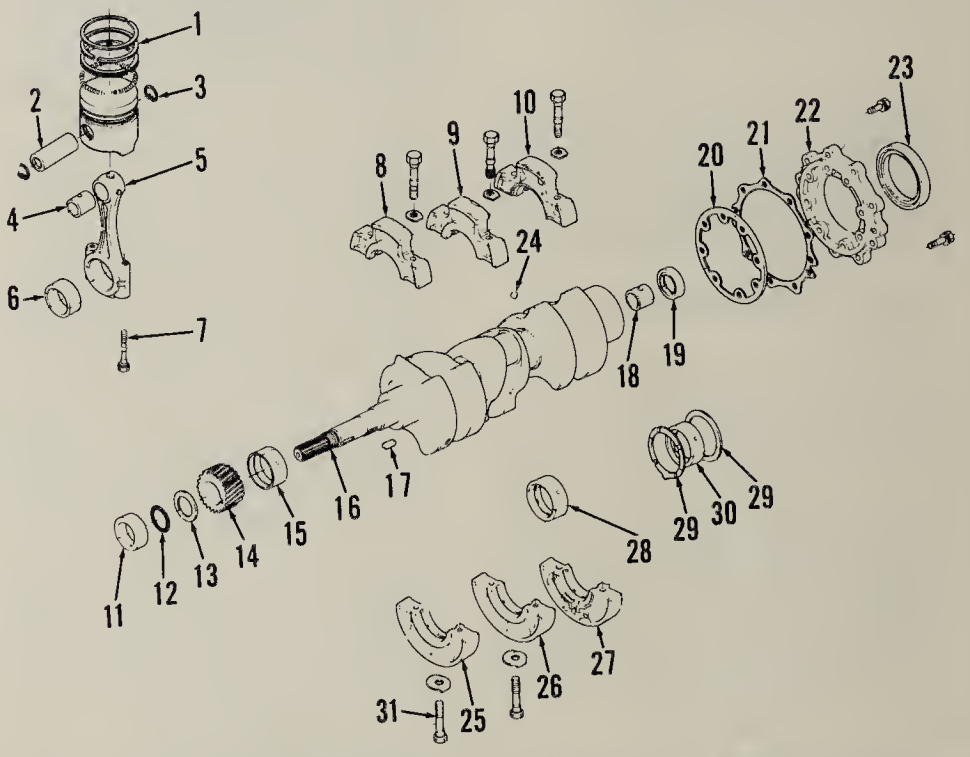


Fig. K2-20—Exploded view of piston, rod and crankshaft assembly.

1. Piston rings
2. Piston pin
3. Retainer
4. Bushing
5. Connecting rod
6. Bearing
7. Screw
8. Upper bearing carrier half, front
9. Upper bearing carrier half, middle
10. Upper bearing carrier half, rear
11. Spacer
12. "O" ring
13. Oil slinger
14. Gear
15. Bearing
16. Crankshaft
17. Key
18. Bushing
19. Seal
20. Gasket
21. Gasket
22. Seal carrier
23. Seal
24. Plug
25. Lower bearing carrier half, front
26. Lower bearing carrier half, middle
27. Lower bearing carrier half, rear
28. Main bearing
29. Thrust washers
30. Rear main bearing
31. Locator screw

PISTON, PIN AND RINGS

All models are equipped with two compression rings and an oil control ring. Pistons are aluminum and cam-ground. Piston and rings are available in 0.5 mm (0.020 inch) oversize as well as standard size.

Insert piston rings squarely into cylinder bore, then measure end gap with a feeler gage. On all models except D950-B, recommended end gap is 0.25-0.40 mm (0.010-0.016 inch) for compression rings and 0.20-0.40 mm (0.008-0.016 inch) for oil control ring. On Model D950-B, end gap for compression rings should be 0.30-0.45 mm (0.012-0.018 inch) and 0.25-0.40 mm (0.010-0.016 inch) for oil control ring.

Use a feeler gage to check side clearance of second compression ring and oil control ring in piston ring grooves. Top compression ring is a keystone type ring and side clearance is not measured. Recommended side clearance is 0.085-0.112 mm (0.0033-0.0044 inch) for second compression ring and 0.020-0.055 mm (0.001-0.002 inch) for oil control ring.

A full floating piston pin is used on all models. Piston pin boss inner diameter should be 20.000-20.013 mm (0.7874-0.7879 inch) with a wear limit of 20.03 mm (0.7886 inch). Outside diameter of piston pin should be 20.002-20.011 mm (0.7875-0.7878 inch).

When reinstalling rings, note location and shape of rings as shown in Fig. K2-18. Stagger ring end gaps around piston 180 degrees from each other.

CYLINDER LINER

All models are equipped with dry type cylinder liners. Use suitable removal and installation tools to renew defective liners. When renewing liner, be sure to thoroughly clean outer surface of liner and cylinder bore, then apply a light coat of oil to liner and bore surfaces. Press liner into crankcase so top of liner is flush with top of crankcase within plus or minus 0.025 mm (0.001 inch). After installation, liner must be honed to final size.

Standard inner diameter of cylinder liner is 64.000-64.019 mm (2.5197-

2.5204 inches) for Model D650-B; 68.00-68.019 mm (2.6772-2.6779 inches) for Models D750-B, Z500-B and ZB500C-B; 72.000-72.019 mm (2.8346-2.8353 inches) for Models D850-B, DH850-B, Z600-B and ZB600C-B or 75.000-75.019 mm (2.9528-2.9535 inches) on Model D950-B. Maximum allowable liner wear is 0.15 mm (0.006 inch). Standard cylinder liner may be bored for 0.5 mm (0.020 inch) oversize piston installation.

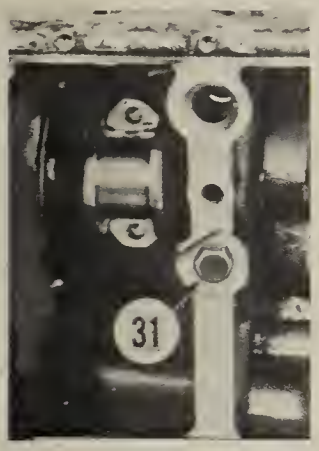


Fig. K2-21—View showing location of locating screw (31) which secures bearing carrier to block.

CONNECTING ROD AND BEARINGS

Connecting rods are equipped with a renewable bushing in the small end and a precision, insert type bearing in the big end. Inner diameter of big end bearing should be 37.004-37.050 mm (1.4569-1.4587 inches). Clearance between crankpin and bearing should be 0.029-0.091 mm (0.0011-0.0036 inch) while maximum allowable clearance is 0.20 mm (0.008 inch). Bearings are available in 0.20 and 0.40 mm (0.008 and 0.016 inch) undersizes.

Small end bushing inner diameter should be 20.025-20.040 mm (0.7884-0.7890 inch). Recommended clearance between piston pin and bushing is 0.014-0.038 mm (0.0006-0.0015 inch) while maximum allowable clearance is 0.15 mm (0.006 inch). When renewing bushing, make certain oil hole in bushing is aligned with hole in end of rod. Bushing must be honed to provide desired clearance for piston pin.

CAMSHAFT

R&R OVERHAUL. To remove camshaft, first remove cylinder head and timing gear cover as previously outlined. Remove cam followers (tappets) from their bores. Unscrew camshaft retainer plate (9–Fig. K2-19) cap screws, then withdraw camshaft and gear assembly. If necessary, press camshaft gear (8) off camshaft.

Camshaft lobe height should be 26.88 mm (1.0583 inches) with a wear limit of 26.83 mm (1.0536 inches). Camshaft bearing journal diameter should be 32.934-32.950 mm (1.2966-1.2972 inches) while inner diameter of camshaft bearing bores is 33.000-33.025 mm (1.2992-1.3002 inches). Maximum allowable clearance between camshaft journal and bearing bore is 0.15 mm (0.006 inch). With camshaft supported in V-blocks at outer bearing journals, maximum allowable runout measured at either center bearing journal is 0.02 mm (0.0008 inch).

When installing camshaft gear on camshaft, first install retainer (9–Fig. K2-19). Heat camshaft gear to approximately 80°C (175°F), then push gear onto camshaft. Refer to TIMING GEARS AND COVER section to align timing gear marks during camshaft installation.

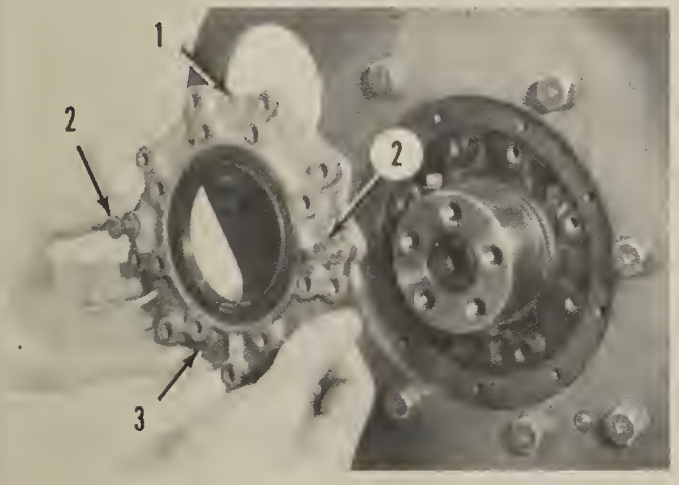


Fig. K2-22—Be sure mark (1) is positioned at top when reinstalling crankshaft rear seal retainer plate (3). Cap screws (2) are used in jackscrew holes to remove retainer plate.

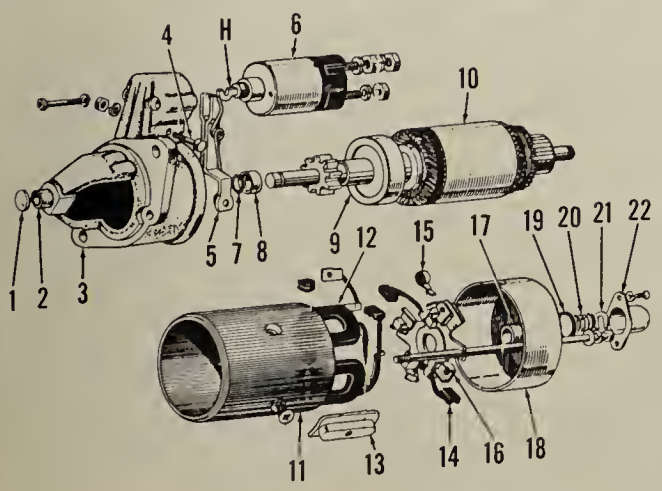


Fig. K2-33—Exploded view of electric starter.

1. Cap
2. Bushing
3. Drive housing
4. Pivot bolt
5. Fork
6. Solenoid
7. Snap ring
8. Collar
9. Starter drive
10. Armature
11. Frame
12. Field coils
13. Field magnets
14. Brush
15. Brush spring
16. Brush plate
17. Bushing
18. End frame
19. Packing
20. Spring
21. Spring retainer
22. Cap

CRANKSHAFT AND BEARINGS

R&R AND OVERHAUL. To remove crankshaft, remove pistons and rods, timing gear cover, crankshaft gear, flywheel and seal carrier (22–Fig. K2-20). Free bearing carriers (25, 26 and 27) by unscrewing locating screws (31–Fig. K2-20 or K2-21). Carefully withdraw crankshaft and bearing carrier assembly out rear of cylinder block. Note that bearing carriers are a tight fit in cylinder block to prevent oil loss between oil passages in block and bearing carriers. Remove screw securing bearing carrier halves and separate halves from crankshaft. Note that main bearing carriers are not interchangeable.

Standard main journal diameter is 43.934-43.950 mm (1.7297-1.7303 inches). Main bearing clearance for front bearing (15–Fig. K2-20) should be 0.034-0.106 mm (0.0013-0.0042 inch) while clearance for all other bearings should be 0.034-0.092 mm (0.0013-0.0036 inch).

Standard diameter of crankpin journals is 36.959-36.975 mm (1.4551-1.4557 inches). Recommended clearance between crankpins and rod bearings is 0.029-0.091 mm (0.0011-0.0036 inch).

Crankshaft end play should be 0.15-0.31 mm (0.006-0.012 inch) and is controlled by thrust washers (29–Fig. K2-20) located on either side of rear main bearing. Thrust washers are available in oversize thicknesses of 0.2 mm (0.008 inch) and 0.4 mm (0.016 inch). Install thrust washers so grooved side faces away from bearing carrier.

Inspect rear oil seal (23 – Fig. K2-20) and renew if necessary. Lubricate seal lip with oil prior to assembly.

To reinstall crankshaft, proceed as follows: Be sure main bearing carriers are correctly positioned on crankshaft, then tighten bearing case cap screws to 20-24 N·m (15-17 ft.-lbs.). Carefully reinstall crankshaft assembly into crankcase and tighten bearing carrier locating screws (31) to 30-34 N·m (22-25 ft.-lbs.). When reinstalling rear seal carrier (3 – Fig. K2-22), be sure mark (1) is positioned at top. Tighten seal retainer cap screws in a diagonal pattern to 10-12 N·m (7-9 ft.-lbs.). When reinstalling flywheel, turn crankshaft until number 1 crankpin is at top dead center. Align TC mark on flywheel with punch mark on rear plate, then install flywheel and tighten mounting screws in a diagonal pattern to 54-59 N·m (40-43 ft.-lbs.). Complete installation by reversing the removal procedure.

ELECTRICAL SYSTEM

The alternator should produce 14 volts with a minimum charging current of 8.5 amperes.

Refer to Fig. K2-23 for an exploded view of electric starter motor used on all models. With no load imposed on starter, the starter shaft should rotate at 5000 rpm or more while drawing less than 50 amperes current and 11 volts.

Minimum brush length is 10.5 mm (0.413 inch). Pinion engagement depth is adjusted by turning hook (H – Fig. K2-23). With starter pinion in engaged position, distance between collar (8) and pinion should be 0.1-0.4 mm (0.004-0.016 inch). Turn hook (H) so pinion engagement depth is correct.

KUBOTA

Model	No. Cyls.	Bore	Stroke	Displ.
DH1101-B	3	76 mm (2.99 in.)	82 mm (3.23 in.)	1115 cc (68 cu. in.)
D1102-B, D1102-BC	3	76 mm (2.99 in.)	82 mm (3.23 in.)	1115 cc (68 cu. in.)
D1301-B, D1302-B	3	82 mm (3.23 in.)	82 mm (3.23 in.)	1299 cc (79.3 cu. in.)
D1402-B	3	85 mm (3.35 in.)	82 mm (3.23 in.)	1395 cc (85.1 cu. in.)
S2200-B	6	76 mm (2.99 in.)	82 mm (3.23 in.)	2231 cc (136.1 cu. in.)
S2600-B	6	82 mm (3.23 in.)	82 mm (3.23 in.)	2598 cc (158.5 cu. in.)
V1501-B	4	76 mm (2.99 in.)	82 mm (3.23 in.)	1487 cc (90.7 cu. in.)
V1502-B, V1502-BC	4	76 mm (2.99 in.)	82 mm (3.23 in.)	1487 cc (90.7 cu. in.)
V1701-B, V1702-B	4	82 mm (3.23 in.)	82 mm (3.23 in.)	1732 cc (105.7 cu. in.)
V1902-B	4	85 mm (3.35 in.)	82 mm (3.23 in.)	1861 cc (113.6 cu. in.)
VT1502-B	4	76 mm (2.99 in.)	82 mm (3.23 in.)	1487 cc (90.7 cu. in.)
Z751-B	2	76 mm (2.99 in.)	82 mm (3.23 in.)	743 cc (45.3 cu. in.)
Z851-B	2	82 mm (3.23 in.)	82 mm (3.23 in.)	866 cc (52.8 cu. in.)

All engines in this section are liquid-cooled, four-stroke diesel engines having two, three, four or six-cylinders.

MAINTENANCE

LUBRICATION

Recommended crankcase oil is SAE 10W or SAE 10W-30 when ambient temperature is below 0°C (32°F), SAE 20 when temperature is between 0°-25°C (32°-77°F) or SAE 30 when temperature is above 25°C (77°F). Manufacturer recommends using oil with API classification CD.

All models are equipped with a pressure lubrication system. Oil is directed from the oil pump to the oil pressure relief valve and oil filter. Oil is routed through a passage in cylinder block to the crankshaft and to the cylinder head to lubricate the valve train. Normal oil pressure at rated speed is 295-441 kPa (43-64 psi) on Models S2200-B, S2660-B, Z751-B and Z851-B or 295-392 kPa (43-57 psi) on all other models.

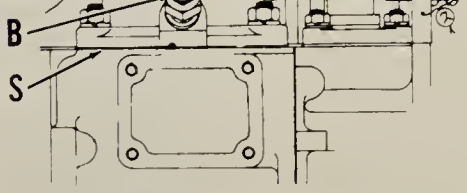


Fig. K3-1—injection timing is adjusted by adding or deleting shims (S) between pump and engine block.

FUEL SYSTEM

FUEL FILTER. A renewable fuel filter is mounted on side of engine. Manufacturer recommends renewing filter element after every 400 hours of operation. However, if engine indicates signs of fuel starvation (loss of power or surging), renew filter regardless of hours of operation. After renewing filter, air must be bled from system as outlined in the following paragraph.

BLEED FUEL SYSTEM. To bleed air from fuel system, first remove bleed screw on fuel filter mounting bracket. Open fuel valve, then reinstall bleed screw when air-free fuel flows. Loosen injection pump bleed screw (B–Fig. K3-1). On models equipped with a fuel transfer pump, rotate crankshaft with starter to operate fuel transfer pump. On all models, tighten bleed screw after fuel flows from bleeder.

If engine fails to start at this point, loosen high pressure lines at injectors. With throttle control lever in full speed position, crank engine to operate injection pump. Retighten injector line fittings when fuel is discharged from injector lines, then start engine.

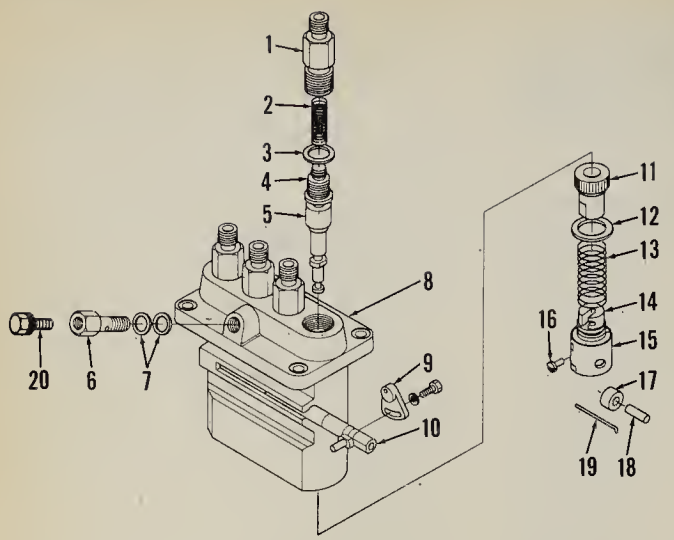


Fig. K3-2—Exploded view of injection pump used on four-cylinder engines. Other models are similar. A jetstart cock is installed in place of bleed screw (20) on some models.

1. Delivery valve holder
2. Spring
3. Gasket
4. Delivery valve assembly
5. Pumping element
6. Inlet fuel fitting
7. Gaskets
8. Pump body
9. Plate
10. Control rack
11. Control sleeve
12. Washer
13. Spring
14. Spring seat
15. Tappet
16. Guide pin
17. Roller
18. Pin
19. Retainer wire
20. Bleed screw

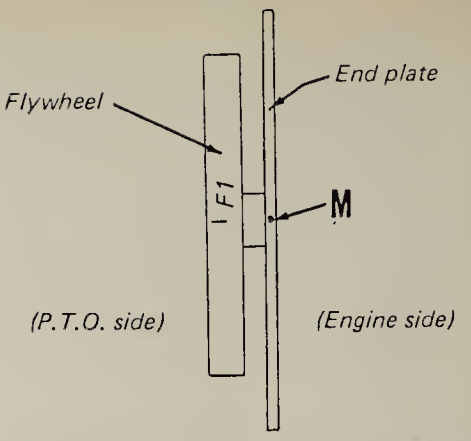


Fig. K3-3—View of "F1" injection timing mark on flywheel of all models and timing mark (M) on end plate of models so equipped. Refer to text.

INJECTION PUMP TIMING. Injection pump timing is adjusted using shims (S–Fig. K3-1). To check injection pump timing, proceed as follows: Disconnect high pressure line for number 1 cylinder from injection pump, then unscrew delivery valve holder (1–Fig. K3-2) and valve assembly (4). Remove valve spring (2) and delivery valve. Reinstall delivery valve holder (1) and connect a suitable spill pipe to valve holder. Aim spill pipe at a receptacle to catch discharged fuel. Move throttle control to full speed position. Rotate engine flywheel slowly in counterclockwise direction until fuel just stops flowing from spill pipe. On models equipped with a flywheel housing, remove timing cover. Flywheel mark "F1" should be aligned with timing mark (M–Fig. K3-3) on cylinder block rear plate or timing pointer on flywheel housing.

To adjust injection timing, remove injection pump and add or delete shims (S–Fig. K3-1). Each shim alters timing approximately 1½ crankshaft degrees. Add shims to retard timing or delete shims to advance timing. Be sure pump control rack pin properly engages operating fork when installing pump. Tighten pump retaining nuts or screws to 24-27 N·m (18-20 ft.-lbs.). Reinstall delivery valve and spring and tighten delivery valve holder to 40-49 N·m (30-36 ft.-lbs.).

GOVERNOR

All models are equipped with a flyball type governor mounted on front end of fuel injection pump camshaft. Refer to Fig. K3-4 for an exploded view of governor linkage.

Slow idle speed for all models is 800 rpm and is adjusted by turning idle speed screw (3–Fig. K3-4). High idle speed and maximum fuel limiting stop screws are sealed and should be adjusted by qualified personnel only. High idle speed should be 2800 rpm for Models S2200-B and S2600-B or 3000 rpm for all other models. Turn high idle speed screw (3) for adjustment.

Maximum fuel limiting stop should be set to prevent excessive smoke level at slight overload. To make adjustment, remove seal cap, loosen jam nut and turn adjusting screw (21) in to lower smoke level or out to raise smoke level.

Some models are equipped with a "torque rise" adjustment screw (12). Position of screw is set at factory and manufacturer does not recommend further adjustment.

COMPRESSION RELEASE

All models are equipped with a compression release which holds exhaust valves open slightly when compression release lever (1–Fig. K3-5) is rotated. To adjust compression release, rotate engine crankshaft so piston in cylinder being adjusted is at top dead center on compression. Remove cover (8), loosen locknut (3) and back out adjusting screw (2). Rotate compression release lever to engaged position. Turn adjusting screw (2) in until it contacts exhaust rocker arm, then turn screw an additional 1½ turns. Tighten locknut. Repeat procedure to adjust remaining cylinders.

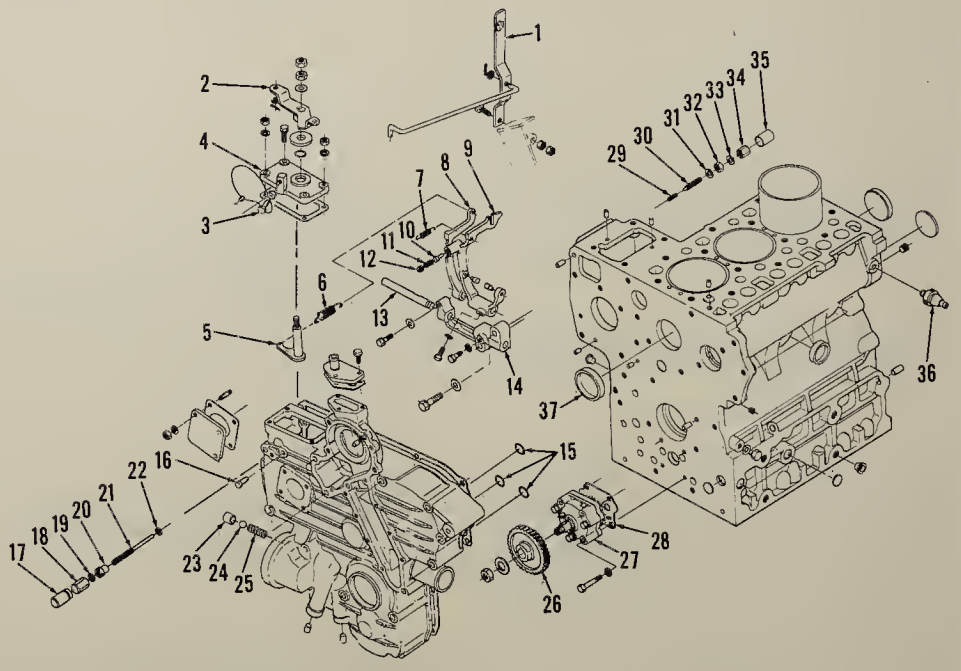


Fig. K3-4—Exploded view of timing gear cover and associated components.

1. Speed control
2. Control lever
3. High idle adjusting screw
4. Plate
5. Control arm
6. Governor spring
7. Start spring
8. Governor arm
9. Governor lever
10. Plunger
11. Spring
12. Set screw
13. Pivot pin
14. Pivot block
15. "O" rings
16. Pin
17. Cap
18. Cap nut
19. Gasket
20. Locknut
21. Maximum fuel limiting screw
22. Gasket
23. Valve seat
24. Relief valve ball
25. Spring
26. Gear
27. Oil pump
28. Gasket
29. Spring
30. Low idle adjusting screw
31. Gasket
32. Locknut
33. Gasket
34. Cap nut
35. Cap
36. Oil pressure sender

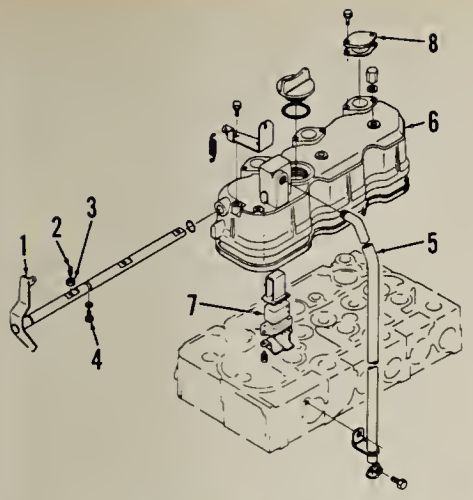


Fig. K3-5—Exploded view of valve cover and compression release components.

1. Compression release shaft
2. Compression release screw
3. Locknut
4. Screw
5. Vent tube
6. Valve cover
7. Breather
8. Cover

Check operation of compression release being sure exhaust valves do not contact pistons.

COOLING SYSTEM

All engines are liquid-cooled with Models Z751-B and Z851-B using thermosiphon circulation while all other models use forced circulation with a centrifugal water pump.

Recommended pressure rating for radiator cap is 88.25 kPa (13 psi). On all models except Z751-B and Z851-B, thermostat opening temperature is about 82°C (180°F). Fan belt tension is correct if finger pressure applied to belt at midpoint between alternator pulley and crankshaft pulley deflects belt about 8 mm (5/16 inch).

AIR FILTER

All models are equipped with a dry type renewable air filter. Manufacturer recommends blowing out filter after every 100 to 200 hours of operation and renewing filter after six cleanings or one year.

REPAIRS

TIGHTENING TORQUES

Connecting rod.....37-41 N·m (27-30 ft.-lbs.)

Crankshaft pulley nut:

S2200-B, S2600-B.....196-215 N·m (145-158 ft.-lbs.)

All other models.....137-156 N·m (101-115 ft.-lbs.)

Crankshaft seal carrier.....24-27 N·m (18-20 ft.-lbs.)

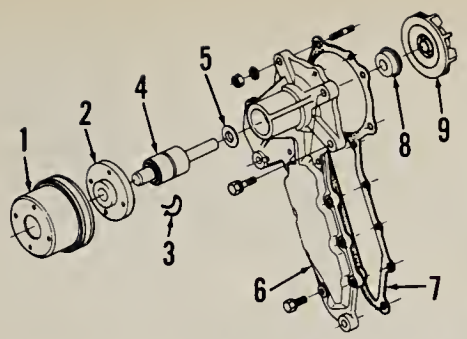


Fig. K3-6—Exploded view of water pump used on all engines except Models Z751-B and Z851-B.

1. Pulley
2. Flange
3. Retainer clip
4. Shaft & bearing assy.
5. Slinger
6. Pump body
7. Gasket
8. Seal
9. Impeller

Cylinder head:

S2200-B, S2600-B.....74-83 N·m (55-61 ft.-lbs.)

All other models.....74-78 N·m (55-58 ft.-lbs.)

Flywheel.....98-108 N·m (73-80 ft.-lbs.)

Injection pump.....24-27 N·m (18-20 ft.-lbs.)

Injector.....30-49 N·m (22-36 ft.-lbs)

Main bearing retainer screw.....64-68 N·m (48-50 ft.-lbs.)

Main bearing case screws...30-34 N·m (22-25 ft.-lbs.)

Oil pump.....10-12 N·m (8-9 ft.-lbs.)

Rocker arm stand.....18-20 N·m (13-15 ft.-lbs.)

Rocker arm cover.....7-9 N·m (5-7 ft.-lbs.)

Timing gear cover.....24-27 N·m (18-20 ft.-lbs.)

WATER PUMP

All Models Except Z751-B and Z851-B

R&R AND OVERHAUL. To remove water pump, drain coolant and if necessary, relocate radiator for access to pump. Remove fan belt, fan, spacer and pulley then unbolt and remove pump from timing gear cover.

Using a suitable puller, pull flange (2–Fig. K3-6) off shaft. Disengage retainer clip (3), then push shaft and bearing assembly (4) out front of housing. Disassemble as required.

Shaft and bearings (4) are available only as a unit assembly.

COMPRESSION PRESSURE

Compression pressure at cranking speed (200-300 rpm) should be 2746-3236 kPa (398-469 psi) for Models Z751-B, DH1101-B, V1501-B and S2200-B; 2844-3334 kPa (412-483) psi for Models Z851-B, D1301-B, V1701-B and S2600-B; or 2944-3234kPa (427-469

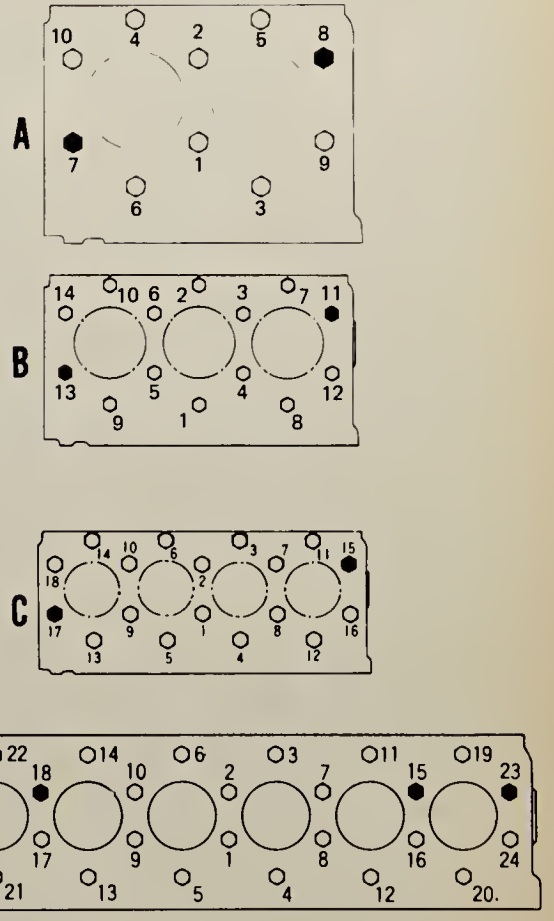


Fig. K3-7—When tightening cylinder head fasteners, follow sequence in drawing (A) for two-cylinder engines; drawing (B) for three-cylinder engines; drawing (C) for four-cylinder engines; drawing (D) for six-cylinder engines. Studs are located at blackened locations.

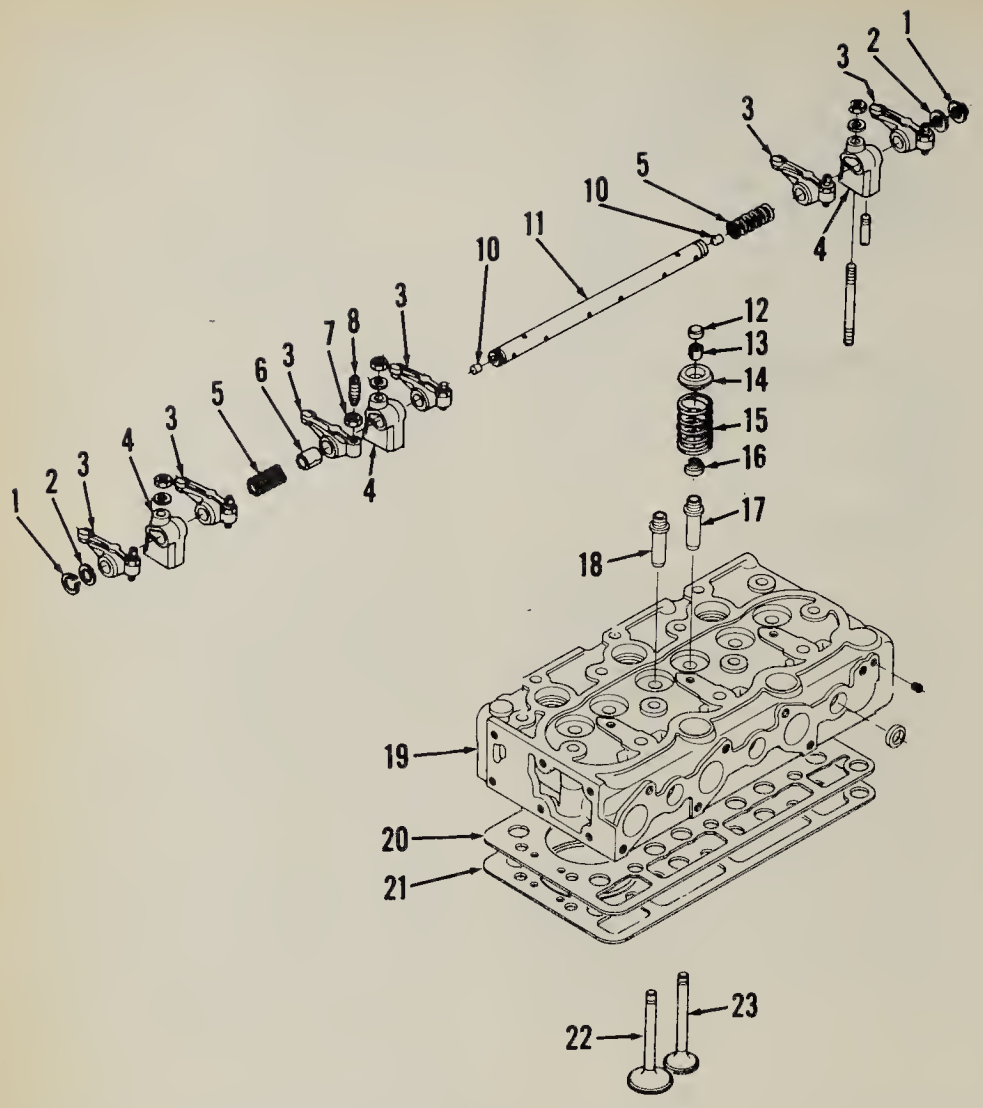


Fig. K3-8—Exploded view of valve train.

1. Snap ring
2. Washer
3. Rocker arm
4. Shaft stand
5. Spring
6. Bushing
7. Locknut
8. Adjusting screw
10. Set screw
11. Rocker shaft
12. Valve cap
13. Retainer keys
14. Retainer
15. Spring
16. Seal
17. Exhaust valve guide
18. Intake valve guide
19. Cylinder head
20. Shim
21. Gasket
22. Intake valve
23. Exhaust valve

psi) on all other models. Compression pressure readings among cylinders should not vary more than 10 percent.

CYLINDER HEAD

R&R AND OVERHAUL. To remove cylinder head, first drain coolant. Disconnect radiator hose and bypass hose. Remove fan belt, alternator and intake and exhaust manifolds. Remove fuel injection lines, injector nozzles and glow plugs. Remove rocker arm cover, rocker arms and shaft assembly and push rods. Unscrew cylinder head retaining cap screws, then remove cylinder head and gasket.

Thoroughly clean cylinder head and crankcase mounting surfaces. Inspect for cracks or other damage. Check flatness of head surface using a straightedge placed along sides and across mating surface. If a 0.05 mm (0.002 inch) feeler gage can be inserted between straightedge and cylinder head surface, head must be resurfaced. After resurfacing head, check piston-to-head clearance as outlined in the following paragraph.

To check clearance between piston and cylinder head, install head and gasket with valves and springs installed but with injectors removed. Tighten cylinder head cap screws to specified torque following appropriate tightening sequence shown in Fig. K3-7. Insert a suitable measuring gage such as soft solder or lead wire through injector opening. Be sure wire does not go between a valve seat and an open valve. Rotate crankshaft by hand until piston being checked passes top dead center. Remove wire and measure thickness to determine piston clearance which should be 0.7-0.9 mm (0.028-0.035 inch). If clearance is less than 0.7 mm (0.028 inch), a shim (20-Fig. K3-8) may be installed between cylinder head and gasket to obtain desired clearance.

Reverse removal procedure to reinstall cylinder head. Refer to appropriate diagram in Fig. K3-7 for cylinder head bolt tightening sequence. Tighten cylinder head bolts evenly in steps to specified torque. Adjust valve clearance and compression release. Operate engine for about 30 minutes, then retorque cylinder head.

VALVE CLEARANCE

Valve clearance should be adjusted with engine cold and piston at top dead center on compression. Remove rocker cover and rotate crankshaft so number 1 piston is at TDC on compression. Turn rocker arm adjusting screws until clearance between rocker arm and valve stem end cap is 0.18-0.22 mm (0.007-0.009 inch) for both valves. Rotate crankshaft until next piston in firing order (1-2-3 for three-cylinder engines, 1-3-4-2 for four-cylinder engines or 1-5-3-6-2-4 for six-cylinder engines) is at TDC on compression. Repeat adjustment procedure for each of the remaining cylinders.

VALVE SYSTEM

Intake and exhaust valves seat directly in cylinder head. Valve face and seat angles are 45 degrees. Desired valve seat width is 2.1 mm (0.083 inch). After refacing valves and seats, check distance valve head is recessed from cylinder head surface. Valve should be recessed 1.1-1.3 mm (0.043-0.051 inch). If recession exceeds 1.6 mm (0.063 inch), a shim washer of appropriate thickness should be added between valve spring and cylinder head to maintain correct valve spring tension and cylinder head surface should be machined to obtain recommended recession.

Valve stem diameter should be 7.960-7.975 mm (0.3134-0.3140 inch) for intake and exhaust. Inside diameter of valve guides should be 8.015-8.030 mm (0.3156-0.3161 inch). Recommended clearance between valve stems and guides is 0.04-0.07 mm (0.0016-0.0028 inch) and maximum allowable clearance is 0.1 mm (0.004 inch). When renewing guides, note that intake and exhuast guides are not interchangeable. After installation, check guide inside diameter and ream to provide recommended clearance for valves.

Intake and exhaust valve springs are identical. Valve spring free length should be 41.7-42.2 mm (1.642-1.661 inches) while installed height is 35.15 mm (1.384 inches). Load required to compress spring to installed height should be 100-117.7 N (22.5-26.5 pounds). Renew spring if it fails to meet test load requirements or if it is distorted or otherwise damaged.

Rocker arm bushings (6–Fig. K3-8) are renewable. Inside diameter of bushing should be 14.002-14.043 mm (0.5513-

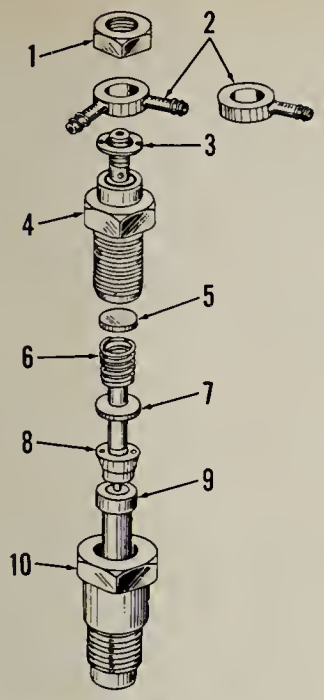


Fig. K3-9—Exploded view of injector.

1. Nut
2. Bypass fitting
3. Washer
4. Pressure fitting
5. Shim
6. Spring
7. Pressure pin
8. Spacer
9. Nozzle & valve
10. Nozzle nut

0.5529 inch). Rocker shaft diameter should be 13.973-13.984 mm (0.5501-0.5506 inch). Recommended clearance between rocker arm shaft and bushings is 0.01-0.07 mm (0.0004-0.0028 inch) while maximum allowable clearance is 0.15 mm (0.006 inch). When renewing rocker arm bushings, make certain oil holes in bushing and rocker arm are aligned.

INJECTOR

WARNING: Fuel emerges from injector with sufficient force to penetrate the skin. When testing injector, keep yourself clear of nozzle spray.

REMOVE AND REINSTALL. Before removing an injector, or loosening injector lines, thoroughly clean injector, lines and surrounding area using compressed air and a suitable solvent.

To remove injector unit, first remove high pressure line leading from injection pump to injector. Disconnect bleed line by removing nut and banjo fitting, or by pulling line(s) from banjo nipple fitting (2—Fig. K3-9). With pressure and bleed-back lines removed, unscrew injector from its mounting position on cylinder head. A special nozzle holder socket wrench, Code No. 07916-30841, is available from manufacturer for use in removing and installing injectors.

When installing injector, make sure that machined seating surface in cylinder head is completely clean and free from carbon buildup. Use a new copper washer underneath injector nozzle and tighten injector carefully to 30-49 N·m (22-36 ft.-lbs.).

TESTING. A complete job of testing and adjusting the injector requires use of special test equipment. Only clean, approved testing oil should be used in tester tank. Nozzle should be tested for opening pressure, seat leakage and spray pattern. When tested, nozzle should open with a high-pitched buzzing sound, and cut off quickly at end of injection with a minimum of seat leakage.

Before conducting test, operate tester lever until fuel flows, then attach injector. Close valve to tester gage and pump tester lever a few quick strokes to be sure nozzle valve is not stuck, and that possibilities are good that injector can be returned to service without disassembly.

OPENING PRESSURE. Open valve to tester gage, then operate tester lever slowly while observing gage reading. Opening pressure should be 13730-14710 kPa (1990-2130 psi).

Opening pressure is adjusted by adding or removing shims (5-Fig. K3-9). Adding or removing one 0.1 mm (0.004 inch) thickness shim will change opening pressure approximately 980 kPa (140 psi).

SEAT LEAKAGE. Operate tester lever slowly to maintain pressure at 1000 kPa (150 psi) below nozzle opening pressure and observe nozzle tip for leakage. If a drop forms within a period of 10 seconds, nozzle valve is not seating and must be overhauled or renewed.

SPRAY PATTERN. Spray pattern should be well atomized and slightly conical, emerging in a straight axis from nozzle tip. If pattern is wet, ragged or intermittent, nozzle must be overhauled or renewed.

OVERHAUL. Hard or sharp tools, emery cloth, grinding compound or other than approved solvents or lapping compounds must never be used. An approved nozzle cleaning kit is available through a number of specialized sources.

Wipe all dirt and loose carbon from exterior of nozzle and holder assembly. Refer to Fig. K3-9 for exploded view and proceed as follows:

Secure nozzle in soft jawed vise or holding fixture and remove cap nut (10). Place all parts in clean calibrating oil or diesel fuel as they are removed. Use compartmented pan and use extra care to keep parts from each injector together and separate from other units which are disassembled at the same time.

Clean exterior surfaces with a brass wire brush. Soak parts in an approved carbon solvent, if necessary, to loosen hard carbon deposits. Rinse parts in clean diesel fuel or calibrating oil immediately after cleaning to neutralize the solvent and prevent etching of polished surfaces.

Clean nozzle spray hole from inside using a pointed hardwood stick or wood splinter as shown in Fig. K3-10. Scrape carbon from pressure chamber using hooked scraper as shown in Fig. K3-11. Clean valve seat using brass scraper as shown in Fig. K3-12, then polish seat using wood polishing stick and mutton tallow as in Fig. K3-13.

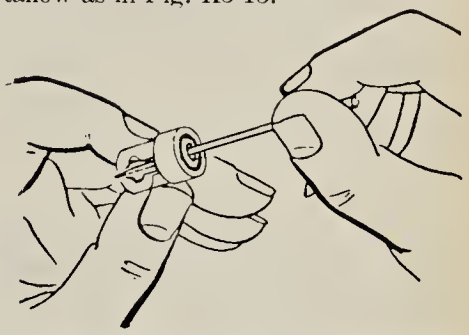


Fig. K3-10—Use a pointed hardwood stick to clean spray hole as shown.

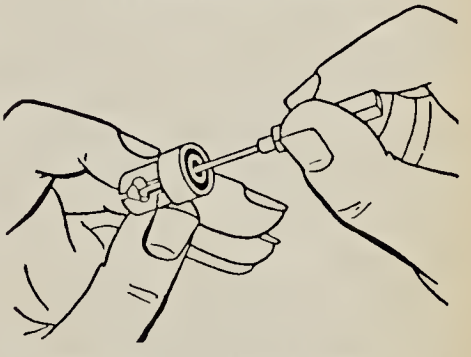


Fig. K3-11—Use a hooked scraper to clean carbon from pressure chamber.

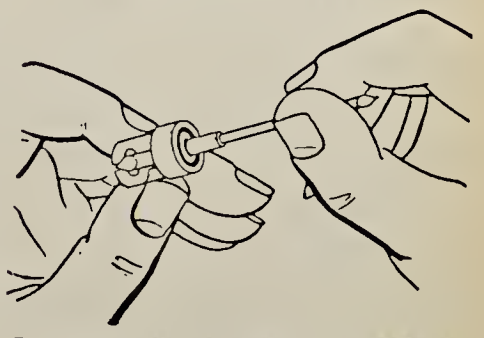


Fig. K3-12—Clean valve seat using brass scraper as shown.

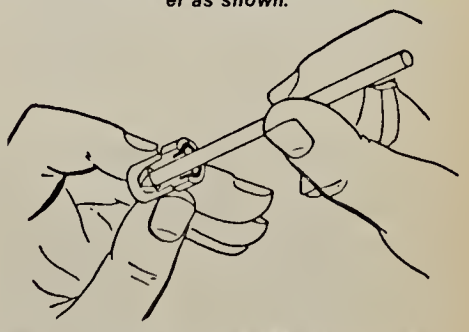


Fig. K3-13—Polish nozzle seat using polishing stick and mutton tallow.

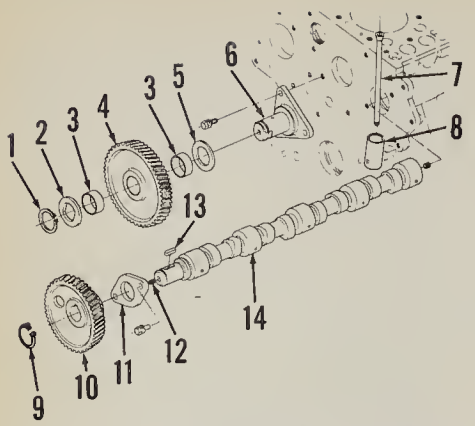


Fig. K3-14—Exploded view of camshaft and idler gear assemblies.

1. Snap ring
2. Slotted washer
3. Bushing
4. Idler gear
5. Washer
6. Idler shaft
7. Push rod
8. Tappet
9. Snap ring
10. Gear
11. Retainer
12. Plug
13. Key
14. Camshaft

NOTE: Nozzle valve needle must slide freely in nozzle valve body. If needle sticks, reclean or renew nozzle valve assembly (9—Fig. K3-9).

Back flush nozzle using reverse flusher adapter. Reclean all parts by rinsing thoroughly in clean diesel fuel or calibrating oil and assemble while parts are immersed in clean fluid. Make sure adjusting shim pack is intact. Tighten nozzle retaining nut (10 – Fig. K3-9) to a torque of 59-78 N·m (44-58 ft.-lbs.). Do not overtighten as distortion may cause valve to stick, and no amount of overtightening can stop a leak caused by scratches or dirt. Retest assembled injector as previously outlined.

GLOW PLUGS

Glow plugs are parallel connected with each individual glow plug grounding through its mounting threads. The glow plug indicator light will glow after about 30 seconds if glow plugs are operating satisfactorily, and will fail to glow if circuit is open.

If indicator light fails to glow, check for loose connections at switch, indicator lamp and glow plugs. Using an ohmmeter, check resistance of each glow plug. Resistance between glow terminal and body should be 1.5-1.6 ohms. If resistance is zero, glow plug is shorted. If resistance is infinite, glow plug element is broken.

INJECTION PUMP

All models are equipped with an injection pump similar to type shown in Fig. K3-2. Before removing pump, thoroughly clean pump, fuel lines and surrounding area. After disconnecting fuel lines, immediately plug all openings to prevent entrance of dirt.

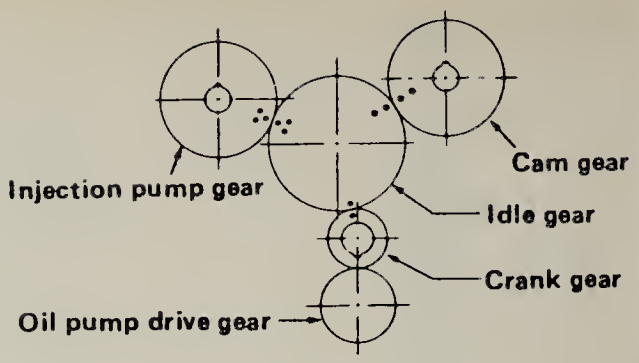


Fig. K3-15—Diagram of drive gears and properly aligned timing marks. Note that some models use two side-by-side marks on camshaft gear in place of the two in-line marks as shown. No marks are used on oil pump drive gear.

The injection pump should be tested and overhauled by a shop qualified in diesel injection pump repair. The injection pump is actuated by lobes on the injection pump camshaft (14 – Fig. K3-18). Inspect camshaft whenever injection pump is removed.

To reinstall injection pump, reverse the removal procedure. Be sure pump control rack pin engages slot in governor linkage. Tighten retaining nuts and cap screws to 24-27 N·m (18-20 ft.-lbs.). Bleed air from system and check pump timing as outlined in previous section.

TIMING GEARS AND COVER

REMOVE AND REINSTALL. To remove timing gear cover, first drain coolant and relocate radiator. Remove injection pump cover from side of crankcase and detach governor spring (6 – Fig. K3-4) from governor arm (8). Detach throttle control linkage, then remover speed control plate (4) and governor spring. Remove start spring (7) from timing gear cover. Remove fan belt and fan. Unscrew crankshaft pulley nut, then remove pulley using a suitable puller. Remove retaining cap screws, then withdraw timing gear cover.

Backlash between any two gears should be 0.04-0.11 mm (0.0017-0.0045 inch). Maximum allowable backlash is 0.15 mm (0.006 inch). Idler gear bushings (3 – Fig. K3-14) and stub shaft (6) are renewable. Refer to appropriate sections for service procedures covering remainder of gears.

When reinstalling gears, make certain timing marks on crankshaft gear, cam-

Fig. K3-16—Measure clearance between inner and outer pump rotors as shown. Refer to text.

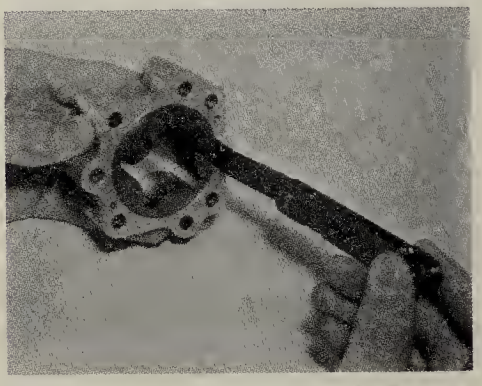
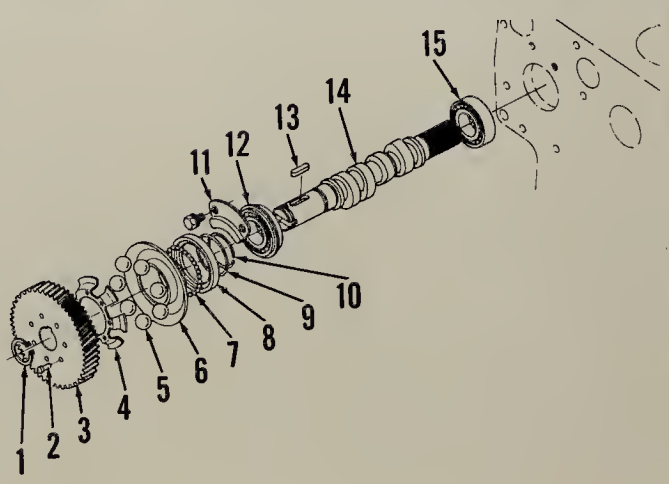


Fig. K3-17—Measure clearance between outer rotor and oil pump body es shown. Refer to text.

Fig. K3-18—Exploded view of injection pump camshaft and governor components.

1. Snap ring
2. Pin
3. Gear
4. Ball guide
5. Large governor balls
6. Sleeve
7. Small governor balls
8. Ball case
9. Retainer ring
10. Retainer ring
11. Bearing retainer
12. Bearing
13. Key
14. Injection pump camshaft
15. Bearing



shaft gear, injection pump camshaft gear and idler gear are aligned as shown in Fig. K3-15. Be sure to renew crankshaft "O" ring (14 – Fig. K3-20) and oil seal (12). Lubricate oil seal lip and "O" ring with oil prior to reassembly. Be sure the three "O" rings (15 – Fig. K3-4) are in place in front cover, then reinstall cover and tighten cap screws to 24-27 N·m (18-20 ft.-lbs.). Tighten crankshaft pulley nut to 196-215 N·m (145-158 ft.-lbs.) on Models S2200-B and S2600-B or 137-156 N·m (101-115 ft.-lbs.) on all other models. Complete installation by reversing removal procedure.

OIL PUMP

To remove oil pump, first remove timing gear cover as previously outlined. Unbolt and remove oil pump assembly.

Clearance between inner and outer rotor, measured as shown in Fig. K3-16, should be 0.04-0.13 mm (0.0016-0.0051 inch) on Models V1502-B, V1702-B and V1902-B or 0.10-0.16 mm (0.0039-0.0063 inch) on all other models. Maximum allowable clearance is 0.20 mm (0.008 inch) for all models. Clearance between outer rotor and pump body, measured as shown in Fig. K3-17, should be 0.11-0.19 mm (0.0043-0.0075 inch) for all models. Maximum allowable clearance is 0.25 mm (0.010 inch). Individual pump components are not available; pump must be serviced as a unit assembly.

An oil pressure relief valve is located in the oil filter mounting pad.

GOVERNOR AND FUEL CAMSHAFT

All models are equipped with a flyball type governor as shown in Fig. K3-18. Ball movement against governor sleeve (6) actuates governor lever (9 – Fig. K3-4) which is connected to injection pump control rack. Flyball movement is balanced by governor spring (6).

Governor components are accessible after removing timing gear cover and injection pump camshaft gear (3 – Fig. K3-18). Note that 39 loose balls (7) are contained in ball case (8).

Examine sleeve (6), balls (5) and ball travel surface on back of gear for furrowing or pitting and renew if damaged. Be sure governor linkage moves freely. Inspect fuel camshaft (14) and bearings for wear or other damage and renew if necessary.

PISTON AND ROD UNITS

Connecting rod and piston units may be removed from above after removing cylinder head and oil pan. Be sure to remove ring ridge (if present) from top of cylinder before attempting to push piston out. Be sure to identify piston and rod and the cylinder from which it was removed so units can be reinstalled in their original positions. Before removing piston from connecting rod, mark top of piston in relation to alignment marks on connecting rod (Fig. K3-19) and identify piston and connecting rod as a pair to ensure correct assembly.

When reinstalling piston and rod units, be sure numbers stamped on sides of rod and cap are on the same side and aligned with mark made on top of piston. Install piston and rod unit so numbers on rod and cap face away from camshaft side of engine. Lubricate threads of connecting rod cap screws with engine oil, then tighten evenly to 37-41 N·m (27-30 ft.-lbs.).

PISTON AND RINGS

All models are equipped with two compression rings and an oil control ring surrounding an aluminum, cam-ground piston. Piston and rings are available in standard size and 0.5 mm (0.020 inch) oversize.

Recommended piston ring end gap is 0.03-0.45 mm (0.012-0.018 inch) for top and second compression rings and 0.25-0.45 mm for oil control ring. Maximum allowable ring end gap is 1.25 mm (0.049 inch) for all rings.

To check ring groove wear, measure side clearance of second compression ring and oil control ring in piston ring grooves. Top compression ring is a keystone type ring and side clearance is not measured. Recommended ring groove side clearance for second compression ring is 0.09-0.12 mm (0.004-0.005 inch) and 0.02-0.05 mm (0.001-0.002 inch) for oil control ring. Renew piston if side clearance is excessive.

When installing rings onto piston, be sure manufacturer's name or "TOP" mark on ring is towards top of piston.

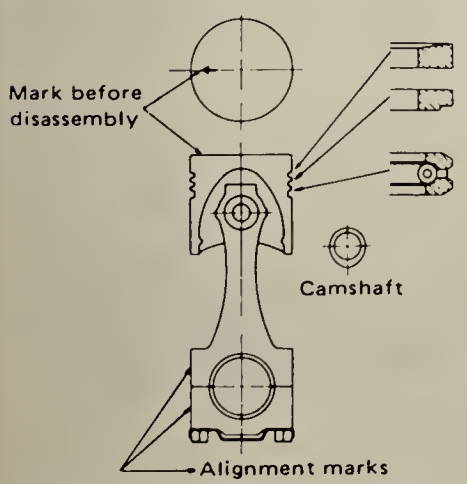


Fig. K3-19—Before removing piston, mark piston crown in relation to alignment marks on connecting rod. Marks must face away from camshaft side of engine.

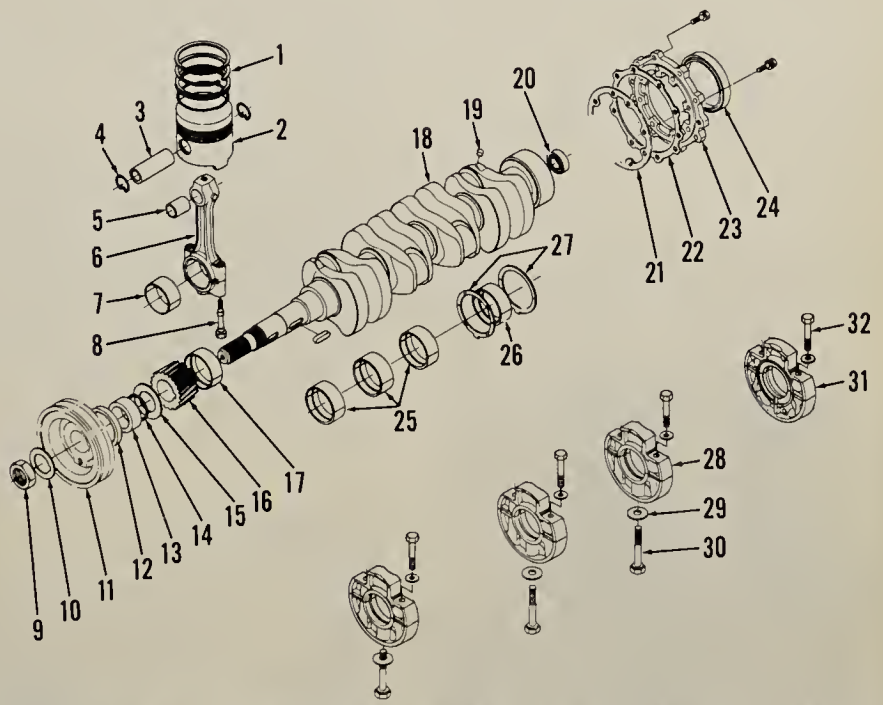


Fig. K3-20—Exploded view of piston, connecting rod and crankshaft assembly. On Models S2200-B and S2600-B, main bearing carriers (28) are retained by side screws as well as locating screws (30).

1. Piston rings
2. Piston
3. Piston pin
4. Retainer
5. Bushing
6. Connecting rod
7. Bearing
8. Screw
9. Nut
10. Washer
11. Pulley
12. Oil seal
13. Spacer
14. "O" ring
15. Oil slinger
16. Gear
17. Bearing
18. Crankshaft
19. Plug
20. Ball bearing
21. Gasket
22. Gasket
23. Seal carrier
24. Oil seal
25. Bearings
26. Bearing
27. Thrust washers
28. Bearing carriers
29. Washer
30. Screw
31. Rear bearing carrier
32. Screw

Make sure notched outer edge on second compression ring (Fig. K3-19) is facing down. Position joint of coil expander opposite of oil control ring end gap. Stagger rings on piston so end gaps are 90 degrees apart with no gap in line with piston pin.

PISTON PIN

A full floating piston pin is used on all models. Pin is retained in piston by a snap ring at each end of pin.

Piston pin outside diameter should be 23.002-23.011 mm (0.9056-0.9059 inch). Inside diameter of piston pin bosses should be 23.002-23.013 mm (0.9055-0.9060 inch) while the wear limit is 23.053 mm (0.9076 inch). Desired piston pin fit in piston bosses is 0.011 mm (0.0004 inch) interference to 0.011 mm (0.0004 inch) clearance.

It is recommended that piston be heated prior to reassembly to ease installation of pin.

CYLINDER LINER

All models are equipped with dry type cylinder liners. Use suitable removal and installation tools to renew defective liners. When renewing liner, be sure to thoroughly clean outer surface of liner and cylinder bore, then apply a light coat of oil to liner and bore surfaces. Press new liner into crankcase so top of liner is flush with top of crankcase within plus or minus 0.025 mm (0.001 inch). After installation, liner must be honed to final size.

Standard inner diameter of cylinder liner is 76.0-76.019 mm (2.9921-2.9929 inches) for Models Z751-B, DH1101-B, D1102-B, V1501-B, V1502-B and S2200-B; 82.0-82.022 mm (3.2283-3.2292 inches) for Models Z851-B, D1301-B, D1302-B, V1701-B, V1702-B and S2600-B; 85.0-85.022 mm (3.3465-3.3473 inches) for Models D1402-B and V1902-B. Maximum allowable liner wear is 0.15 mm (0.006 inch). Standard diameter cylinder liner may be bored for 0.5 mm (0.020 inch) oversize piston installation.

CONNECTING ROD AND BEARINGS

Connecting rods are equipped with a renewable bushing in the piston pin end and a precision, insert type bearing in the crankpin end.

Inner diameter of crankpin end bearing should be 44.010-44.052 mm (1.7327-1.7343 inches). Clearance between crankpin and bearing should be 0.035-0.093 mm (0.0014-0.0037 inch) while maximum allowable clearance is 0.2 mm (0.008 inch).

Small end bushing inner diameter should be 23.025-23.040 mm (0.9065-0.9071 inch). Recommended clearance between piston pin and bushing is 0.014-0.038 mm (0.0006-0.0015 inch) while maximum allowable clearance is 0.15 mm (0.006 inch). When renewing bushing, make certain oil hole in bushing is aligned with hole in end of rod. After installation, bushing must be honed to provide desired piston pin clearance.

CAMSHAFT

R&R AND OVERHAUL. To remove camshaft, remove cylinder head and timing gear cover as previously outlined then remove tappets. Unscrew camshaft retainer plate (11-Fig. K3-14) and withdraw camshaft from cylinder block. If necessary, press camshaft gear (10) off camshaft.

Camshaft lobe height should be 33.36 mm (1.3134 inches) for intake and exhaust. Cam lobe wear limit is 33.31 mm (1.3114 inches). Camshaft bearing journal diameter should be 39.934-39.950 mm (1.5722-1.5728 inches) while inner diameter of bearing bores should be 40.000-40.025 mm (15.748-1.5758 inches). Renew camshaft if clearance between camshaft journal and bearing exceeds 0.15 mm (0.006 inch).

When installing camshaft gear on camshaft, first install retainer (11-Fig. K3-14). Heat gear to approximately 80°C (175°F), then push gear onto camshaft.

To reinstall camshaft, reverse the removal procedure. Refer to TIMING GEARS AND COVER section to properly align timing marks during installation.

CRANKSHAFT AND BEARINGS

R&R AND OVERHAUL. To remove crankshaft, remove pistons and rods, timing gear cover, crankshaft gear, flywheel and seal carrier (23-Fig. K3-20). Free bearing carriers (28) by unscrewing locating screws (30-Fig. 3-21) in underside of block and also in side of block on Models S2200-B and S2600-B. Carefully withdraw crankshaft and bearing carrier assembly out rear of cylinder block. Note that bearing carriers are a tight fit in cylinder block to prevent oil loss between oil passages in block and bearing carriers. Remove screws securing bearing carrier halves and separate halves from crankshaft. Note that main bearing carriers are not interchangeable.

Standard diameter of crankpin journal is 43.959-43.975 mm (1.7307-1.7313 inches). Recommended clearance between crankpins and rod bearings is 0.035-0.093 mm (0.0014-0.0037 inch).

Standard main journal diameter is 51.921-51.940 mm (2.0441-2.0449 inches). Desired main bearing clearance for front bearing is 0.040-0.118 mm (0.0016-0.0046 inch) while desired clearance for all other bearings is 0.040-0.104 mm (0.0016-0.0041 inch). Maximum allowable clearance for all bearings is 0.2 mm (0.008 inch).

Crankshaft end play should be 0.15-0.31 mm (0.006-0.012 inch) and is controlled by thrust washers (27-Fig.

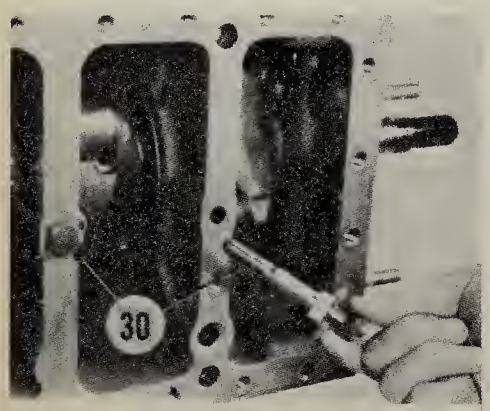
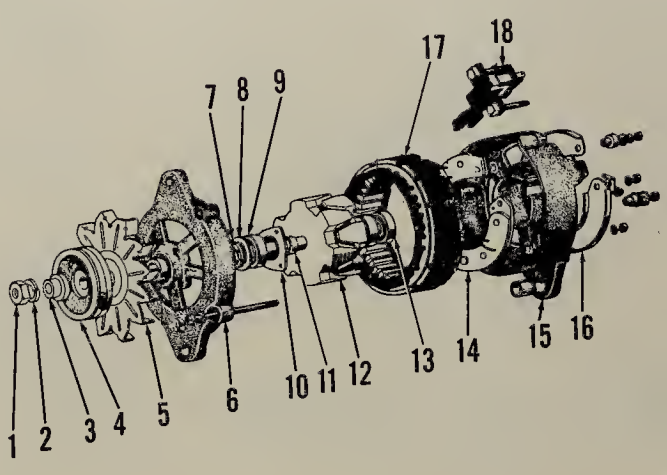


Fig. K3-21—View showing locating screws (30) which secure main bearing carriers to crankcase. Models S2200-B and S2600-B are equipped with screws in side of block that secure bearing carriers.

Fig. K3-22—Exploded view of typical alternator.

1. Nut
2. Lockwasher
3. Spacer
4. Pulley
5. Fan
6. End frame
7. Oil felt
8. Cover
9. Bearing
10. Bearing retainer
11. Spacer
12. Rotor
13. Bearing
14. Rectifier
15. Housing
16. Cover
17. Stator
18. Brush assy.



K3-20) located on each side of rear main bearing carrier (31). When installing thrust washers, make certain grooved side faces away from bearing carrier.

Inspect oil seal (24) and renew if necessary. Be sure to lubricate seal lip prior to reassembly.

To reinstall crankshaft, proceed as follows: Be sure bearing carriers are properly located on crankshaft. Tighten bearing carrier cap screws to 30-34 N·m (22-25 ft.-lbs.). Assemble crankshaft in crankcase, then tighten bearing carrier locating screws to 64-68 N·m (47-50 ft.-lbs.). Tighten flywheel mounting screws to 98-108 N·m (72-80 ft.-lbs.). Complete installation by reversing the removal procedure.

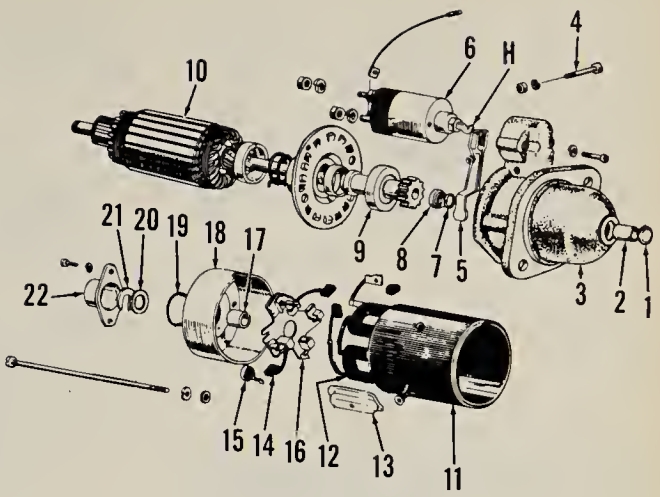


Fig. K3-23—Exploded view of electric starter used on Models D1102-B, D1102-BC, DH1101-B, D1302-B, Z751-B and Z851-B.

1. Cap
2. Bushing
3. Drive housing
4. Pivot bolt
5. Fork
6. Solenoid
7. Snap ring
8. Collar
9. Starter drive
10. Armature
11. Frame
12. Field coils
13. Field magnets
14. Brush
15. Brush spring
16. Brush plate
17. Bushing
18. End frame
19. Packing
20. Spring
21. Spring retainer
22. Cap

ELECTRICAL SYSTEM

ALTERNATOR AND REGULATOR

ALTERNATOR. An alternator rated at 20 amperes output is used on Models Z751-B, Z851-B and DH1101-B while all other models are equipped with a 25-ampere output alternator. Refer to Fig. K3-22 for an exploded view of typical alternator used on all models.

New brush length is 15.5 mm (0.610 inch); renew brush if worn to 10 mm (0.394 inch) or less. To check stator assembly, use an ohmmeter and check continuity between "N" terminal and each stator lead. If continuity does not exist, renew stator. Check continuity between "N" terminal and stator frame. If continuity exists, renew stator.

Using an ohmmeter, check diodes in rectifier assembly (14). Ohmmeter should read infinity during one test then continuity in other test with ohmmeter leads reversed. Individual diodes are not available and rectifier must be renewed as an assembly.

REGULATOR. Voltage regulator is available only as an assembly and adjustment is not normally required. Output voltage is controlled at 13.6-14.6 volts, with a rated output of 10 amperes.

With wiring disconnected or regulator removed, check regulator using an ohmmeter as follows:

Touch ohmmeter leads to IG and F terminals of regulator. Ohmmeter should read zero. If cover is removed and upper voltage control points manually opened, 11 ohms resistance should exist across resistor.

Touch ohmmeter leads to L and E terminals of regulator. Ohmmeter should read zero. If cover is removed and light relay points opened, 100 ohms resistance should exist across voltage regulator coil.

Touch ohmmeter leads to N an E terminals of regulator. Reading should be approximately 32 ohms.

Infinite resistance should exist between B terminal and any other terminal unless regulator cover is removed and light relay armature pushed down to connect lower set of points. With armature depressed, zero resistance should exist between L and B terminals and 100 ohms resistance should exist between E and B terminals.

STARTER. Refer to Fig. K3-23 or K3-24 for an exploded view of electric starter.

MODEL Z751-B. Minimum brush length is 10.7 mm (0.421 inch) while minimum commutator diameter is 32.5 mm (1.279 inch). With no load imposed on starter and using an 11 volt source, the starter shaft should rotate at 5000 rpm or more while drawing less than 50 amperes current.

Pinion engagement dept is adjusted by turning hook (H – Fig. K3-23). With starter pinion in engaged position, distance between collar (8) and pinion should be 0.1-0.4 mm (0.004-0.016 inch). Turn hook (H) so pinion engagement depth is correct.

MODELS Z851-B, DH1101-B, D1102-B, D1102-BC and D1302-B. Minimum brush length is 12.7 mm (0.5 inch) while minimum commutator diameter is 32.5 mm (1.279 inch). With no load imposed on starter, the starter shaft should rotate at 6000 rpm or more while drawing less than 45 amperes current at a voltage of 11.0.

Pinion engagement depth is adjusted by turning hook (H – Fig. K3-23. With starter pinion in engaged postion, distance between collar (8) and pinion should be 0.1-0.4 mm (0.004-0.016 inch). Turn hook (H) so pinion engagement depth is correct.

ALL OTHER MODELS. Minimum brush length is 12.7 mm (0.5 inch) while minimum commutator diameter is 29 mm (1.142 inch). With no load imposed on starter and using an 11.5 volt source, the starter shaft should rotate at 3500 rpm or more while drawing less than 90 amperes current.

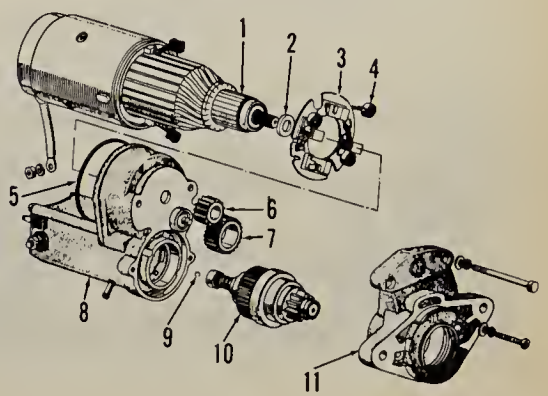


Fig. K3-24—Exploded view of electric starter used on all models except D1102-B, D1102-BC, DH1101-B, D1302-B, Z751-B and Z851-B.

1. Armature
2. Gasket
3. Brush plate
4. Brush spring
5. Gasket
6. Drive gear
7. Driven gear
8. Switch assy.
9. Ball
10. Clutch assy.
11. Gear housing

LISTER

LISTER-PETTER
555 East 56 Highway
Olathe, Kansas 66061

Model	No. Cyls.	Bore	Stroke	Displ.
LT1	1	82.55 mm (3.25 in.)	76.2 mm (3.0 in.)	408 cc (25 cu. in.)
LV1	1	85.73 mm (3.37 in.)	82.55 mm (3.25 in.)	477 cc (29 cu. in.)
LV2	2	85.73 mm (3.37 in.)	82.55 mm (3.25 in.)	954 cc (58 cu. in.)

Lister diesel engine build type can be identified by the last two digits of engine number found on plate (Fig. L1) attached to air shield or fan shroud.

All models are four-stroke, vertical cylinder, air-cooled, direct injection diesel engines. Standard crankshaft rotation is counterclockwise from flywheel end. Metric fasteners are used throughout engine.

MAINTENANCE

STARTING PROCEDURE

Engine may be equipped with either a manual or electric starter. To start engine, refer to Fig. L2 on Models LT1 and LV1, rotate stop lever (A) fully clockwise to "excess fuel" start position. On Model LV2, an automatic excess fuel device is used. Excess fuel device is activated whenever stop lever is moved counterclockwise to "stop" position and then released. On models equipped with a variable speed control lever, move lever towards "fast" position. On all models, move compression release lever (B) towards the flywheel. On manual start engines, lightly oil end of starting shaft. Insert handle and crank engine. If equipped with electric start, crank engine with starter motor. When sufficient cranking speed is obtained, move compression release lever towards fuel tank and continue cranking until engine fires. Remove manual crank handle from the shaft.

CAUTION: Do not allow handle to continue to rotate on running shaft.

Turn stop lever back to "run" position (Models LT1 and LV1). Adjust speed as required if equipped with variable speed control.

LUBRICATION

Engines must use heavy-duty diesel lubricating oil that equals or exceeds API classification CC. If engine is operated under heavy load or high temperature, or if sulfur content in fuel exceeds 0.6 percent, API service classification CD oil is recommended. However, manufacturer does not recommend using CD classification oil in new or reconditioned engines until after the first oil change or 250 hours of operation. Multigrade oil may be used which meets specifications M1L-L46152-B or M1L-L2104C.

Recommended oil change interval is every 250 hours of operation with filter (if so equipped) renewed at same time. However, if engine is operated under heavy load and high temperature or over 3000 rpm, oil should be renewed after every 125 hours of operation. Crankcase capacity is 1.3 liters (1.4 quarts) for Model LT1 or 3.6 liters (3.8 quarts) for Models LV1 and LV2. Do not overfill.

If operating temperatures fall below −15°C (5°F), SAE 5W oil should be used. For temperatures between −15°C (5°F) and 4°C (40°F), use SAE 10W. If temperatures are between 4°C (40°F) and 30°C (85°F), SAE 20W-20 is recommended. For temperatures above 30°C (85°F), SAE 30 should be used.

Refer to Fig. L3 for a cut-away view of typical lubricating system.

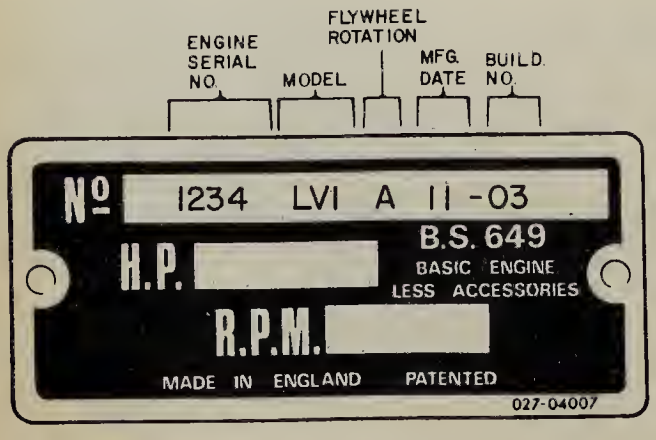


Fig. L1—View of typical engine identification plate. To ensure use of proper parts and specifications, use complete number.

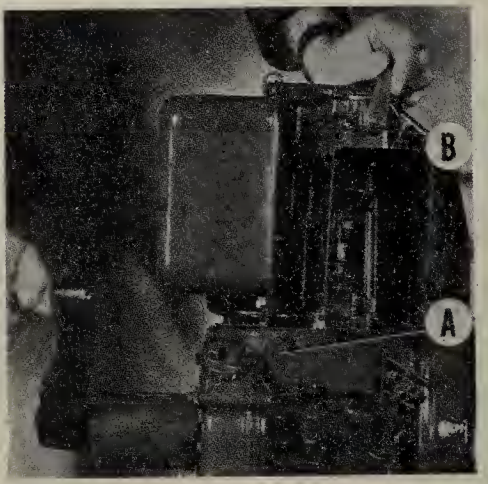


Fig. L2—View of stop lever (A) and compression release lever (B).

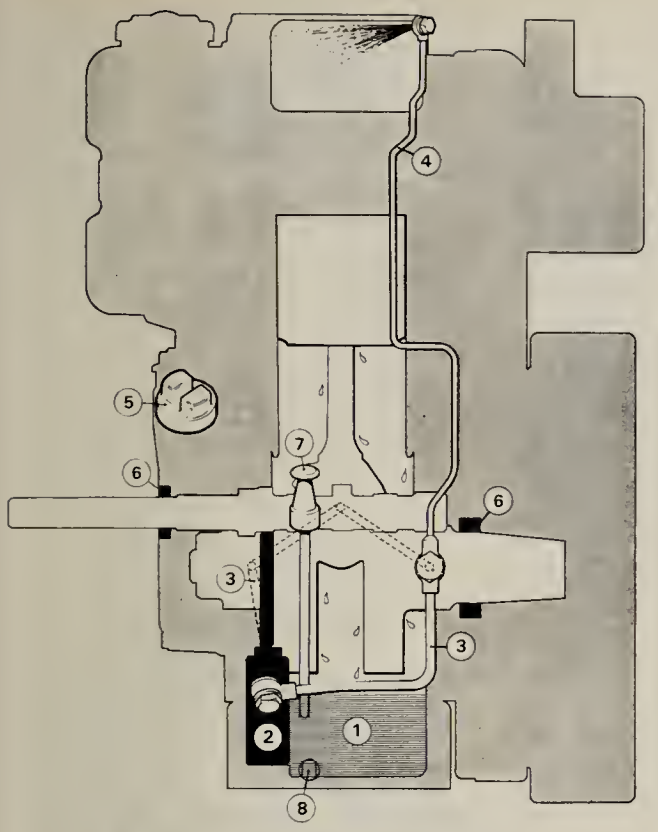


Fig. L3—Cut-away view of lubricating system.
1. Sump
2. Plunger type pump
3. Main bearing oil supply
4. Rocker arm oil supply
5. Filler plug
6. Oil seals
7. Dipstick
8. Drain plug

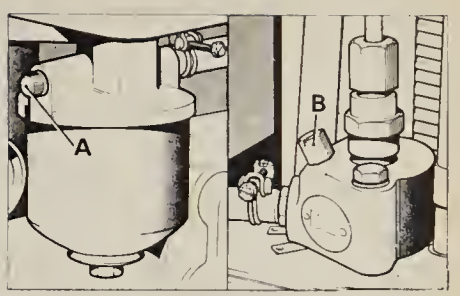


Fig. L4—Air bleed valves are located on fuel filter mounting bracket (A) and fuel pump (B). A self-bleeding system is used on LV1 engines and some LV2 engines.

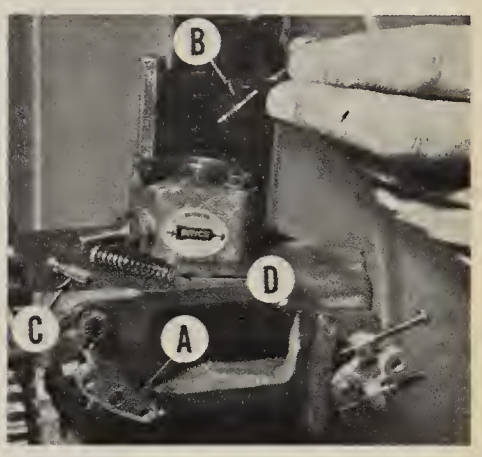


Fig. L5—To time fuel pump, set control lever (A) to "START" position. Disconnect injector pipe and remove delivery valve holder (B), delivery valve (C) and spring (D). Refer to text for details.

FUEL SYSTEM

Number 2 diesel fuel is recommended for most conditions. Number 1 diesel fuel should be used for light duty or cold weather operation.

FILTER AND BLEEDING. Fuel filter element should be renewed after every 500 hours of operation. However, if engine shows signs of fuel starvation (surging or loss of power), renew filter regardless of hours of operation.

Fuel system is equipped with two air bleeder valves (Fig. L4). One valve is located on fuel filter mounting bracket and the other valve is on top side of fuel pump. A self-bleeding system is used in place of pump bleed valve on LV1 engines and some LV2 engines.

INJECTION TIMING. Bryce Berger fuel pump is mounted on side of engine between push rods. Two pumps are used on LV2 engines. Split shims at base of pump are used to adjust injection timing.

To check and adjust pump timing, set control lever to "Start" position. Turn flywheel until timing mark on flywheel is aligned with mark on fan shroud. Be sure both valves are closed on cylinder being timed. Disconnect fuel injector pipe at pump and injector, then remove delivery valve holder (B–Fig. L5), delivery valve (C) and spring (D). If fuel flows from pump, turn crankshaft until flow ceases. Reinstall delivery valve holder. Turn flywheel clockwise about ¼ turn, then slowly turn flywheel counterclockwise (normal direction of rotation) until fuel just stops flowing from delivery valve holder. At this point, beginning of injection occurs and timing marks on flywheel and fan shroud should be aligned. If not, shims below pump body must be added or removed to adjust timing. Add shims to retard timing, subtract shims to advance timing. When timing is correct, tighten pump mounting bolts to 9 N·m (80 in.-lbs.). Reinstall delivery valve and spring and tighten holder to 54 N·m (40 ft.-lbs.). On LV2 engines, repeat procedure to check timing of second pump. Refer to the following chart for specified injection timing.

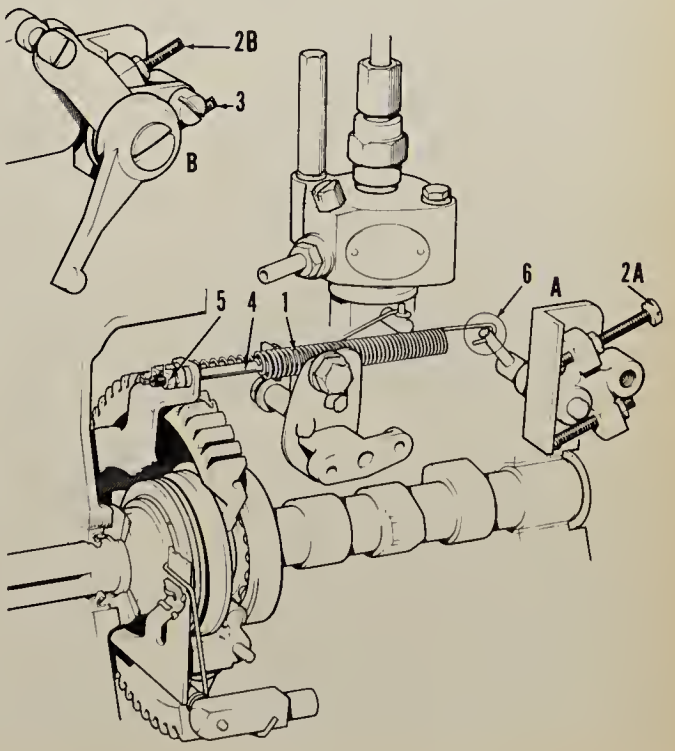


Fig. L6—Two speed controls are used, constant speed (A) and variable speed (B). Speed adjustments are similar. Refer to text for details.
1. Speeder spring
2A. Speed adjusting screw (constant)
2B. Idle speed screw (variable)
3. Maximum speed screw (variable)
4. Governor link
5. Link locknuts
6. Speed control lever pin

LT1 Build No.	Speed Ranges Rpm	Degree BTDC
1,2,4	Up to 2500	24
3,5,6,7,8	2501 and over	27
10,27	Up to 1000	22
11,20	1001 to 1500	26
9,12,13,14, 16,17,19,21, 22,23,25, 26,28,	1501 to 3000	28
15,18,24	3001 to 3600	30

LV1 Build No.	Speed Ranges Rpm	Degree BTDC
9	Up to 1499	22
6	1500 to 1800	24
1,2,3,7,8	1801 to 3000	26
4,5	3001 to 3600	30

LV2 Build No.	Speed Ranges Rpm	Degree BTDC
6	1500 to 1800	24
1,2,3,4,7,8	1801 to 3000	26
5	3001 to 3600	30

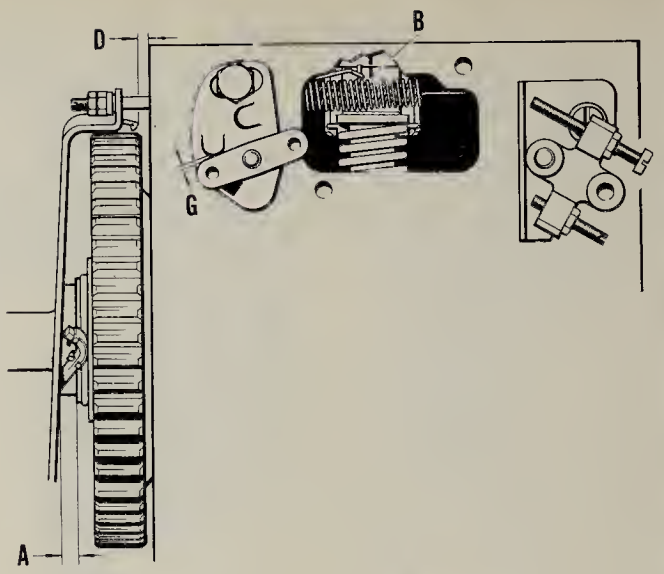


Fig. L7—To check or adjust governor, remove fuel pump inspection plate and timing gear end cover. Set distance (A) to 5.0 mm (0.197 inch) and align calibration mark (B). Governor lever stop to crankcase clearance (D) is 6.8-8.0 mm (0.236-0.315 inch). Refer to text for details.

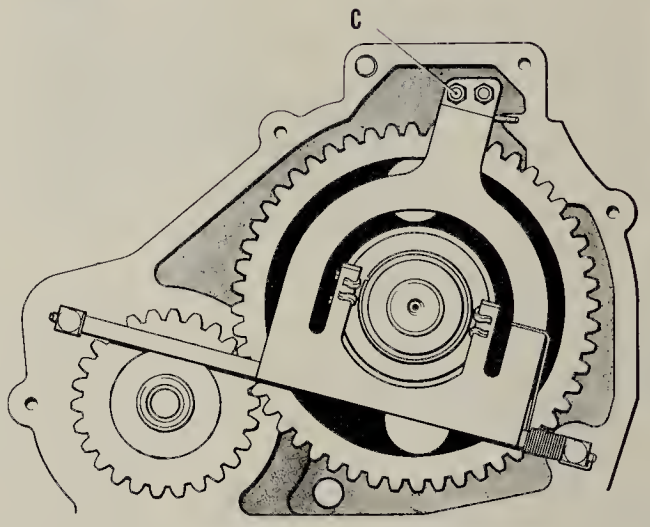


Fig. L8—To align injection pump calibration mark, adjust governor link at (C).

GOVERNOR

To check or adjust governor settings, first remove fuel pump inspection cover and engine end cover. Place engine controls in "Start" position and tap camshaft gently towards flywheel to remove any end play.

Clearance (A–Fig. L7) between thrust sleeve and step on camshaft should be 5.0 mm (0.197 inch) with fuel pump calibration mark (B) aligned with mark on center of fuel pump body. Adjust by altering the length of governor link (C–Fig. L8). On LV2 engines, governor link must be adjusted so calibration marks (B–Fig. L7) are aligned in both pumps.

Set engine control lever to "Run" position. To be sure control lever on LV2 engines is in "Run" position, first turn lever to "Stop" and release. Then, move governor lever away from camshaft until excess fuel device clicks into "Run" position. With fuel pump calibration marks (B) aligned, loosen control lever plate retaining screw and move plate to obtain desired clearance (G–Fig. L7) as listed in Table 1 for load requirement and engine build number.

Excess fuel setting is adjusted by bending wire stop to obtain specified gap (D–Fig. L7) between governor lever stop plate and crankcase. With fuel pump calibration marks (B) aligned, gap (D) should be 6-8 mm (0.236-0.315 inch).

Engines may be equipped with either a constant speed or variable speed control. To adjust idle speed on variable speed control models, turn adjusting screw (2B–Fig. L6) counterclockwise

Table 1-Governor settings.

APPLICATION	LT1 Build No.	LV1 Build No.	LV2 Build No.	Clearance "G"
100% Load	—	9	—	0
	8	—	—	0.4 mm (0.016 in.)
	1,3,5	—	—	0.5 mm (0.020 in.)
	11,20	—	6	0.6 mm (0.024 in.)
	2,4	—	—	0.7 mm (0.028 in.)
	10,15,27	1,6,7	5	1.0 mm (0.040 in.)
	9,12,16 23,26,28	—	3,4	1.2 mm (0.047 in.)
90% Load	6,7,18,24	—	—	0.3 mm (0.012 in.)
	13,14,17, 19,21,22, 25	—	—	0.5 mm (0.020 in.)
	—	2,3,8	—	0.6 mm (0.024 in.)
	—	4,5	—	0.8 mm (0.031 in.)

until it no longer affects engine speed; governor will likely cause engine to "hunt". Turn screw clockwise until "hunting" stops and desired idle speed is obtained, then tighten locknut. Turning upper screw (2A) clockwise increases speed setting on constant speed engines.

The lower screw (3B) is used to limit the maximum speed on variable speed engines. Turning the screw clockwise will reduce maximum speed. Lower screw has no function on constant speed engines.

Governor weights and springs are serviced separately. For proper parts identification and adjustment, contact an authorized service department.

REPAIRS

TIGHTENING TORQUES

Refer to the following table for special tightening torques. Metric fasteners are used throughout engine.

Connecting rod:	
LT1	21 N·m (15 ft.-lbs.)
LV1, LV2	24 N·m (18 ft.-lbs.)
Cylinder head	41 N·m (30 ft.-lbs.)
Flywheel	196 N·m (145 ft.-lbs.)
Injection pipe nuts	28 N·m (21 ft.-lbs.)
Injection pump	9 N·m (80 in.-lbs.)
Injector clamp	21 N·m (15 ft.-lbs.)
Main bearing housing	27 N·m (20 ft.-lbs.)
Manifold upper nuts	21 N·m (15 ft.-lbs.)
Manifold lower nuts	9 N·m (80 in.-lbs.)

VALVE ADJUSTMENT

To adjust valve clearance, turn crankshaft until piston is at TDC on compression stroke (both valves closed). Loosen locknut and turn rocker arm adjusting screw (23–Fig. L10) until appropriate size feeler gage can be inserted between rocker arm and valve stem end. Recommended clearance with engine cold is 0.13-0.18 mm (0.005-0.007 inch) for exhaust on all engines and 0.13-0.18 mm (0.005-0.007 inch) for intake on engines with operating speeds up to 3000 rpm or 0.05-0.10 mm (0.002-0.004 inch) on engines with operating speeds of 3001 to 3600 rpm. Repeat procedure for the other cylinder on LV2 engines.

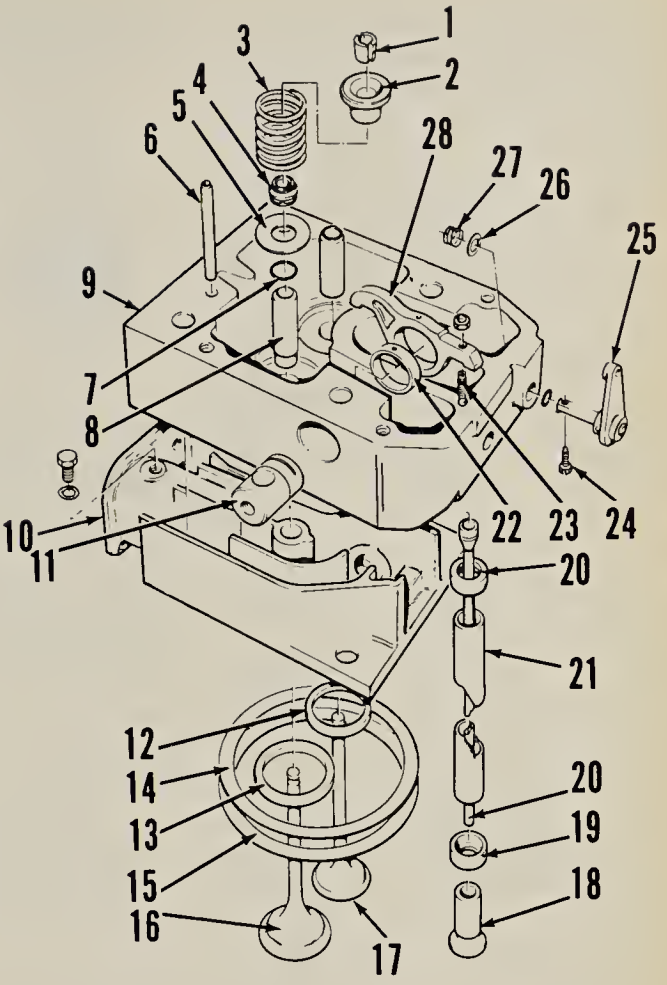


Fig. L10—Exploded view of cylinder head assembly used on LV1 and LV2 engines. LT1 engine is similar.

1. Valve keepers
2. Spring retainer
3. Valve spring
4. Valve seal (intake)
5. Retainer plate
6. Breather tube
7. "O" ring
8. Valve guide
9. Cylinder head (top)
10. Cylinder head (bottom)
11. Rocker arm stub shaft
12. Valve seat insert (exh.)
13. Valve seat insert (int.)
14. Shim
15. Head gasket
16. Intake valve
17. Exhaust valve
18. Tappet
19. Seals
20. Push rod
21. Push rod tube
22. Bushing
23. Adjusting screw
24. Adjusting screw
25. Compression release lever
26. Shim
27. Spring
28. Rocker arm

To adjust compression release lever, piston must be at TDC with both valves closed. With decompressor lever actuated, turn adjusting screw (24) until rocker arm just begins to depress valve, then turn screw clockwise one additional turn.

CYLINDER HEAD

A two-piece cylinder head is used. Top half is cast iron and holds the rocker arm assembly, valve springs, compression release lever and injector. Lower half is aluminum alloy and contains valve seats and a tapped hole in intake port for an oil priming cup used for cold starting. Valve guides are a press fit and hold head together. Refer to Fig. L10.

To remove cylinder head, first remove fuel tank, manifolds, air shield, cylinder head cover, injector clamp and injector. Remove cylinder head retaining nuts, then lift off cylinder head. Be sure to retain head gasket and shims.

To check piston-to-cylinder head clearance, place two pieces of lead wire approximately 1.2 mm (0.047 inch) thick on cylinder head as near as possible in line with pistion pin. Hold wires in place with grease, then reinstall cylinder head and gasket. Tighten cylinder head nuts evenly to 41 N·m (30 ft.-lbs.). Turn piston past top dead center twice, then remove head and measure thickness of wires. Wire thickness (clearance) should be 0.71-0.79 mm (0.028-0.031 inch) for LT1 engines or 0.84-0.91 mm (0.033-0.036 inch) for LV1 and LV2 engines. Clearance is adjusted by installing shims (14–Fig. L10) between cylinder head and head gasket (15).

To reinstall cylinder head, reverse the removal procedure.

NOTE: No sealer is to be used on head gasket; however, a light coating of high melting point grease on the shims and cylinder head side of head gasket is recommended. Do not put grease on cylinder side of gasket. Thread sealer is recommended for cylinder head studs and nuts.

VALVE SYSTEM

The exhaust valve guide is a press fit into both halves of cylinder head. Intake guide is a press fit into the lower half. An "O" ring and retaining plate are located around top of intake guide. When renewing intake guide, "O" ring must be inserted into the top plate recess before pressing guide into head.

Note that guides are marked "IN TOP" and "EX TOP" and must be installed accordingly with lettering on guide at the top. Using suitable tools, press guides in until they extend 12.35-12.60 mm (0.486-0.496 inch) above cylinder head surface on LT1 engine. On LV1 and LV2 engines, top of exhaust guide should be 13.15-13.40 mm (0.518-0.528 inch) above head surface and top of intake guide should project 10.15-10.40 mm (0.400-0.409 inch). After installation, check valve stem clearance in guide and ream guide if necessary. Desired operating clearance is 0.026-0.060 mm (0.001-0.002 inch) for intake and 0.043-0.076 mm (0.002-0.003 inch) for exhaust. Wear limit is 0.07 mm (0.003 inch) for intake and 0.09 mm (0.0035 inch) for exhaust.

Valves seat directly in cylinder head on LT1 engines while LV1 and LV2 engines are equipped with renewable valve seat inserts for both intake and exhaust. When renewing inserts, manufacturer recommends heating cylinder head to 150°C (300°F) and chilling inserts in dry ice before pressing insert into cylinder head counterbore.

Valve face and seat angles are 45° for intake and exhaust. Desired seat width is 1.65-2.29 mm (0.065-0.090 inch) for intake and 1.65-2.01 mm (0.065-0.079 inch) for exhaust. On LT1 and early LV1 and LV2 engines, intake valve should be recessed 0.84-1.15 mm (0.033-0.045 inch) below head surface and exhaust valve should be recessed 1.10-1.41 mm (0.043-0.055 inch). On late LV1 and LV2 engines, valve recession should be 1.00-1.31 mm (0.039-0.052 inch) for intake and 1.10-1.41 mm (0.043-0.055 inch) for exhaust. When servicing early LV1 and LV2 engines, manufacturer recommends grinding valve seats to obtain later engine valve recession values.

Valve spring free length should be 43.7-45.5 mm (1.720-1.791 inches). Renew spring if free length is 42.5 mm (1.673 inches) or less.

INJECTOR

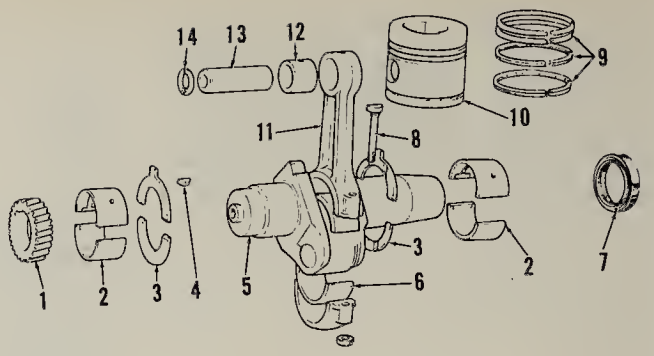
To remove injector, first thoroughly clean injector and surrounding area. Remove cylinder head cover. Disconnect and remove high pressure fuel pipe and return pipe. Remove injector retainer clamp, then remove injector and seal washer.

When reinstalling injector, be sure to renew copper seal washer. Tighten retainer clamp screw to 21 N·m (15 ft.-lbs.).

WARNING: Fuel leaves the injector nozzle with sufficient force to penetrate the skin. When testing, keep yourself clear of nozzle spray.

Fig. L11—Exploded view of crankshaft, connecting rod and piston used on LT1 engines.

1. Crankshaft
2. Main bearings
3. Thrust washers
4. Key
5. Crankshaft
6. Connecting rod bearings
7. Oil seal
8. Rod bolt
9. Piston rings (4)
10. Piston
11. Connecting rod
12. Piston pin bushing
13. Piston pin
14. Retaining ring



To check injector nozzle, connect to a hand test pump and slowly operate pump while observing pressure gage. Nozzle opening pressure for early LT1 engines should be 16210 kPa (2350 psi) for a new nozzle and 15200 kPa (2200 psi) for a used nozzle. On all other engines opening pressure should be 20265 kPa (2940 psi) for new nozzle and 19250 kPa (2790 psi) for a used nozzle. To check nozzle seat for leakage, operate tester to apply a pressure of about 12000 kPa (1750 psi). No leakage should appear at nozzle tip.

To check injector spray pattern, connect injector externally to injection pump using injector high pressure pipe. Set engine control to "Run" position and crank engine at about 60 rpm.

CAUTION: Make certain injector spray is directed away from your person.

If spray seems to be denser in one direction, the nozzle or pintle is dirty. Careful brushing of nozzle tip with a special brass brush will sometimes remove deposits causing the problem. But, if uneven spray continues, complete disassembly and cleaning will be necessary. Such repair should be done by an authorized service department.

INJECTION PUMP

All engines are equipped with a Bryce Berger fuel injection pump. On Model LV2, two pumps (one for each cylinder) are used. The injection pump should be tested and repaired by a shop qualified for diesel injection pump service.

To remove injection pump, first drain fuel from tank. Disconnect and remove fuel lines from pump. Remove fuel pump inspection covers from side of crankcase. Set pump operating lever in center position, then disconnect speeder spring and governor link from pump. Remove pump mounting bolts, then lift out pump. Retain adjusting shims (located under pump) for use in reassembly.

To reinstall pump, reverse the removal procedure. Be sure to reinstall correct shims. Tighten mounting bolts to 9 N·m (80 in.-lbs.). Check governor setting as outlined in GOVERNOR section and refer to INJECTION TIMING section to check and adjust pump timing.

PISTON, PISTION PIN, RINGS AND CYLINDER

A low expansion aluminum alloy piston with recessed combustion chamber is used in all engines. Piston is equipped with two compression rings and two oil control rings.

To remove piston without removing oil sump, proceed as follows: Remove fuel tank and cylinder head as previously outlined. Remove push rod guide and oil feed pipe. Identify air deflector shields so they can be properly reinstalled. Mark position of cylinder barrel to crankcase for use in reassembly, then withdraw cylinder barrel and air deflector shields. Remove piston pin retaining ring, push out pin and remove piston from connecting rod.

Thoroughly clean piston and cylinder barrel and check for scoring, wear or other damage. Piston diameter measured at bottom of skirt should be 82.398-82.423 mm (3.244-3.245 inches) for LT1 and 85.542-85.567 mm (3.3678-3.3668 inches) for LV1 and LV2 engines. Cylinder bore for engines with operating speeds up to 2500 rpm is 82.550-82.575 mm (3.250-3.251 inches) for LT1 engines and 85.750-85.775 mm (3.376-3.377 inches) for LV1 and LV2 engines. Piston clearance in cylinder bore should be 0.127-0.177 mm (0.005-0.007 inch) with maximum allowable wear clearance of 0.22 mm (0.0087 inch).

NOTE: Engines with operating speeds above 2500 rpm are equipped with cylinder barrels which provide an additional 0.025 mm (0.001 inch) piston-to-cylinder clearance over basic engine specifications. These cylinders are identified by a V-shaped notch in top cooling fin. The maximum piston-to-cylinder clearances given for basic engines should be increased by 0.05 mm (0.002 inch) and maximum ring end gaps increased by 0.16 mm (0.006 inch) for these engines.

Piston is fitted with four rings; a barrel faced, keystone type, chrome top ring; a taper faced second compression ring; a spring expander type oil scraper ring mounted above piston pin; and a slotted type oil scraper ring mounted below the piston pin. Piston ring end gap for basic engine (2500 rpm and below) should be 0.30-0.575 mm (0.012-0.022 inch) for top compression ring with a maximum allowable gap of 0.72 mm (0.028 inch). For all other rings, end gap should be 0.20-0.475 mm (0.008-0.018 inch) with a maximum wear limit of 0.67 mm (0.026 inch). Top piston ring groove is keystone type and a special gage is required to measure groove wear. All other ring grooves are rectangular and may be checked for wear by installing rings into grooves and measuring side clearance. Ring side clearance in groove for all rings should be 0.051-0.101 mm (0.002-0.004 inch) with a maximum wear clearance of 0.14 mm (0.0055 inch).

Piston pin diameter should be 28.5674-28.5725 mm (1.1247-1.1249 inches). Operating clearance in rod small end bushing is 0.0385-0.0556 mm (0.0015-0.0022 inch) while maximum allowable clearance is 0.064 inch (0.0025 inch). Pin is a push fit in piston and is retained by two snap rings.

When reassembling make certain piston is installed on connecting rod with the words "MANIFOLD SIDE" correctly postioned. Reinstall rings onto piston making certain second compression ring is installed with side marked "TOP" facing upward. Other rings may be installed either side up. Stagger ring end gaps 90° from each other. Complete installation by reversing the removal procedure.

CONNECTING ROD

A forged steel connecting rod is used with a precision, insert type bearing in the big end. Standard crankpin diameter is 53.977-53.990 mm (2.1251-2.1256 inches). Recommended rod bearing operating clearance is 0.023-0.067 mm (0.001-0.0026 inch) and maximum allowable clearance is 0.09 mm (0.0035 inch). Tighten connecting rod nuts to 21 N·m (15 ft.-lbs.) on Model LT1 and 24 N·m (18 ft.-lbs.) on Models LV1 and LV2.

Small end of rod is fitted with a copper faced bushing. Initial clearance for piston pin in bushing is 0.0385-0.0556 mm (0,0015-0.0022 inch) while maximum allowable clearance is 0.064 mm (0.0025 inch).

END COVER

The end cover (2–Fig. L12) is bolted to gear end of engine and located by two dowels. The cover is fitted with an oil seal for the camshaft extension or crankshaft extension depending on engine type.

To remove end cover, first remove any driven equipment. Remove starter dog (2–Fig. L13) on engines so equipped or spring pin (2–Fig. L14) and starter han-

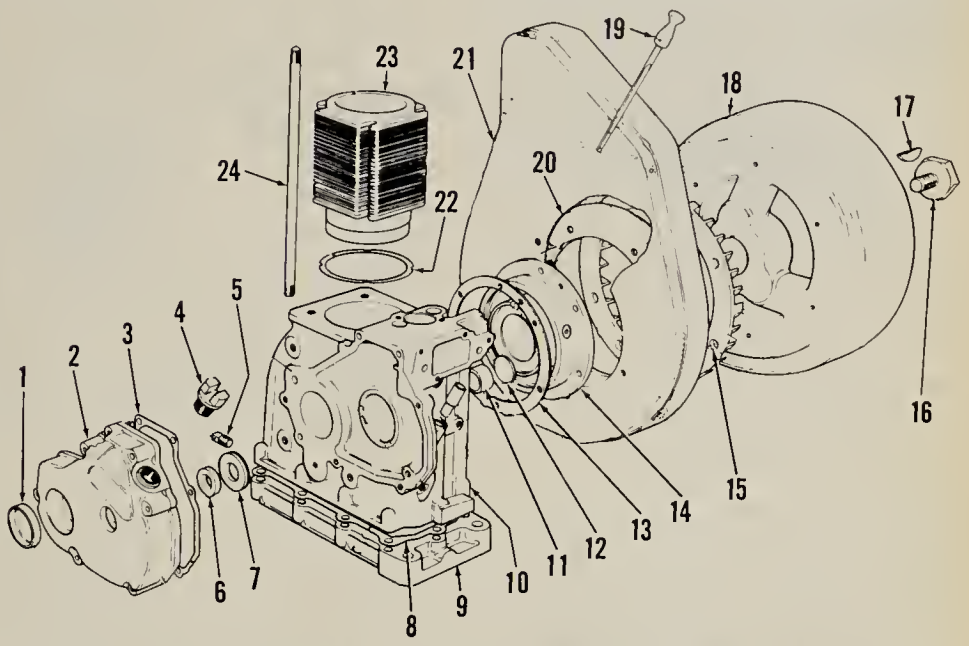


Fig. L12—Exploded view of cylinder block assembly for LT1 engines. Other models are similar.

1. Plug
2. End cover assy.
3. End cover gasket
4. Oil filler plug
5. Drain plug
6. Oil seal
7. Thrust washer
8. Sump gasket
9. Oil sump
10. Crankcase assy.
11. Camshaft bushing
12. Expansion plug
13. Shim
14. Main bearing housing
15. Fan
16. Flywheel screw
17. Key
18. Flywheel
19. Dipstick
20. Air seal
21. Fan shroud
22. Cylinder barrel gasket
23. Cylinder barrel
24. Stud

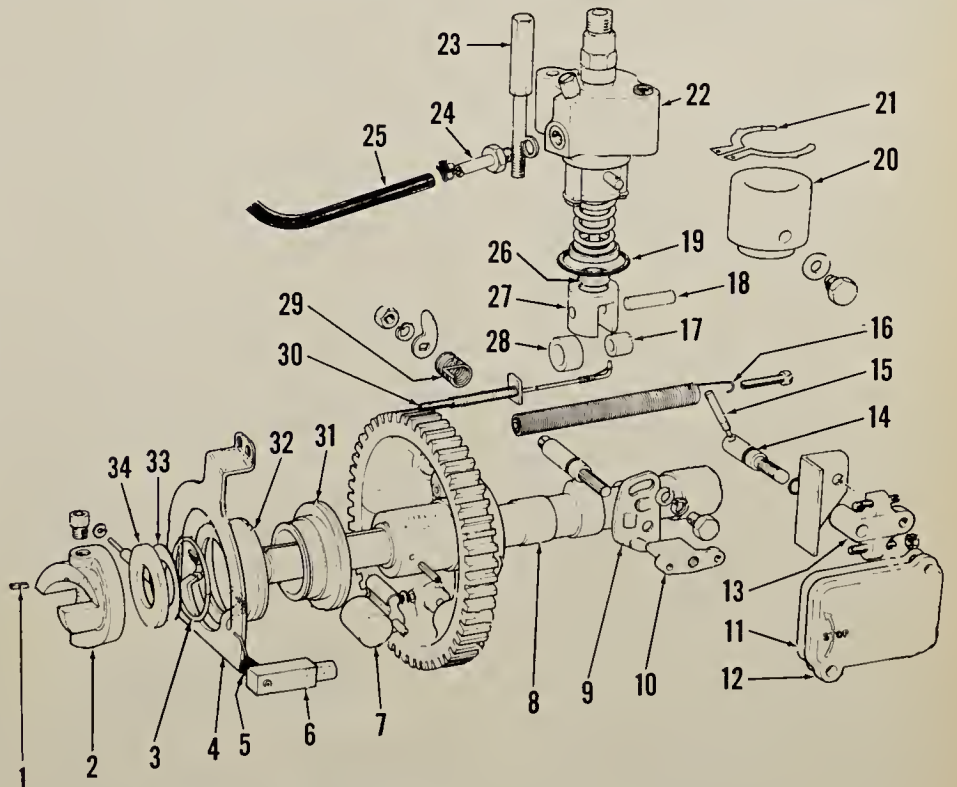


Fig. L13—Exploded view of camshaft, fuel pump and governor assemblies for LT1 engines.

1. Key
2. Starting dog collar
3. Spring ring
4. Governor lever assy.
5. Return spring
6. Pivot block
7. Governor weight
8. Camshaft assy.
9. Control plate
10. Control knob
11. Inspection door gasket
12. Fuel pump inspection door
13. Speed control lever
14. Speed control spindle
15. Speed control lever pin
16. Speeder spring
17. Roller bushing
18. Roller pin
19. Fuel pump "O" ring
20. Fuel pump tappet guide
21. Shims
22. Fuel pump
23. Fuel pump bolt
24. Inlet connector
25. Fuel pipe
26. Insert
27. Fuel pump tappet
28. Roller
29. Control lever spring
30. Governor link assy.
31. Governor sleeve
32. Thrust washer & pad
33. Shim
34. Thrust washer

dle catch pin (3) from camshaft. Unbolt and remove end cover.

Inspect oil seal and renew if necessary. Be sure to protect oil seal lip when reinstalling cover. If cover must be renewed, the bores of the cover must be aligned with camshaft and crankshaft. Be sure shim (33 – Fig. L13) and thrust washer (34) are properly positioned.

CAMSHAFT AND GOVERNOR

The camshaft is supported by a ball bearing at the gear end and a bushing sealed by an expansion plug at the flywheel end. On LV 2 engines, the camshaft is supported by a center bushing also. The governor weights are mounted on pins in the camshaft gear.

To remove camshaft, first remove fuel tank, cylinder head and end cover as previously outlined. Drain oil and remove sump, oil pump and push rod. Disconnect speeder spring (16 – Fig. L13) and remove injection pump (22). Remove locating screw for fuel pump tappet guide (20) and remove tappet (27) and guide. Disconnect rocker arm oil supply pipe from crankcase. Remove retaining clips from push rod guides, then lift push rods and guides out. Lift off governor lever, link and speeder spring. Slide thrust sleeve assembly (31 and 32) off end of shaft. Lift and support tappets. Carefully withdraw camshaft, then remove tappets.

Inspect camshaft and tappets for excessive wear and other damage. Camshaft bearing journal diameter at flywheel end is 25.349-25.362 mm (0.9980-0.9985 inch). Recommended clearance in bushing is 0.038-0.051 mm (0.0015-0.002 inch) while maximum allowable clearance is 0.09 mm (0.0035 inch). On Model LV2, camshaft center bearing journal diameter is 36.942-36.995 mm (1.4544-1.4565 inches). Clearance in bushing should be 0.058-0.071 mm (0.0023-0.0028 inch) and maximum allowable clearance is 0.11 mm (0.004 inch). New bushings should be immersed in engine oil for four hours prior to installation. Special tools are available from manufacturer to properly remove and install bushings. Install new bushing with thinnest part of bearing wall (marked "O") towards the top. Apply sealer to recess in crankcase, then install a new expansion plug.

To renew camshaft ball bearing, drive camshaft gear retaining pin into camshaft until it bottoms. Press gear off camshaft and remove Woodruff key, then press bearing off shaft. Drive spring pin out of camshaft. Press a new bearing onto camshaft. Install Woodruff key, then press gear onto camshaft until it bottoms against shoulder of shaft. Be sure gear retaining pin is driven in below surface of gear hub and any burrs on hub are removed, otherwise, operation of governor thrust sleeve will be affected.

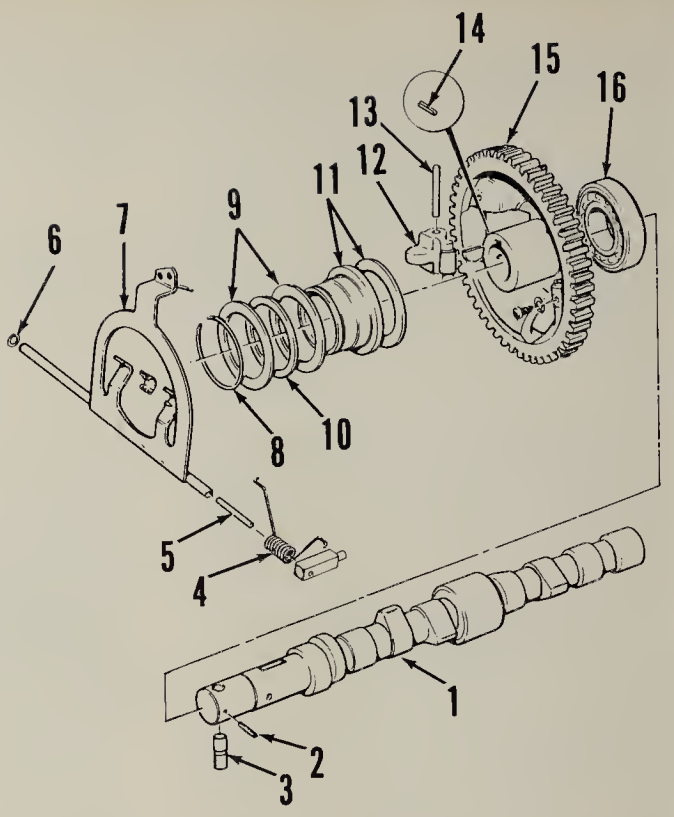


Fig. L14—Exploded view of camshaft and governor assembly for LV2 engines. LV1 engines are similar.

1. Camshaft
2. Pin
3. Starter catch pin
4. Spring
5. Pivot pin
6. Shim
7. Governor lever
8. Retaining ring
9. Thrust washers
10. Thrust pad
11. Sleeve assy.
12. Governor weight
13. Pivot pin
14. Spring pin
15. Camshaft gear
16. Ball bearing

To reinstall camshaft, first insert cam followers and support them in a raised position. Insert camshaft making sure "O" marks (Fig. L15) on camshaft gear and crankshaft gear are aligned. Install thrust sleeve assembly and governor lever assembly. Install shims (6 – Fig. L14) as required to provide governor lever end play of 0.12-0.25 mm (0.005-0.010 inch). Protect oil seal in end cover, then reinstall end cover. Use a dial indicator to check camshaft end play which should be 0.08-0.20 mm (0.003-0.008 inch). Shims are available in different thicknesses to adjust end play, however, only one shim (33 – Fig. L13) of appropriate thickness may be used on LT1 engines or two shims may be used on LV1 and LV2 engines. Complete installation by reversing the removal procedure.

CRANKSHAFT AND MAIN BEARINGS

The crankshaft is supported by two main bearings on LT1 and LV1 engines. An additional center main bearing is used on LV2 engines.

To remove crankshaft, remove fuel tank, oil sump, cylinder head, camshaft, flywheel and fan shroud. Remove cap screws securing main bearing housing, then use a suitable tool to push crankshaft out of crankshaft gear. Remove main bearing housing. Retain shims for use in reassembly. On Model LV2, mark center main bearing housing and crankcase bore to make alignment easier during reassembly. Remove plug adjacent to dipstick and pull center bearing housing locating dowel from crankcase. On all models, carefully withdraw crankshaft from crankcase.

Inspect main bearings and crankshaft journals for excessive wear or other damage. Special tool is available from manufacturer for use in properly removing and installing main bearings. Crankshaft main bearing journal diameter when new is 53.955-53.967 mm (2.1242-1.1247 inches). Recommended operating clearance for main bearings is 0.034-0.089 mm (0.0014-0.0035 inch). Maximum allowable clearance is 0.12

Fig. L15—When installing camshaft or crankshaft gear, align "O" timing marks as shown.

mm (0.005 inch). Main bearings are two-piece inserts and are not interchangeable. Top half of bearing has an oil groove and hole which must be properly aligned. Undersize bearings are available.

Crankpin diameter should be 53.977-53.990 mm (2.1251-2.1256 inches). Desired rod bearing operating clearance is 0.023-0.067 mm (0.0009-0.0026 inch) while maximum allowable clearance is 0.09 mm (0.0035 inch).

Crankshaft end thrust is taken by steel-backed, copper-based, split thrust washers. Thickness of new thrust washer is 2.310-2.360 mm (0.091-0.093 inch). Renew thrust washer if thickness is less than 2.20 mm (0.087 inch).

When reassembling, note that center bearing housing (LV2) is marked "FLYWHEEL END" and must be installed accordingly. Align match marks on bearing housing and crankcase made during disassembly and install alignment dowel. On all models, be sure split thrust washers are installed with copper face towards crankshaft. Tighten main bearing housing mounting screws to 27 N·m (20 ft.-lbs.), then check crankshaft end play using a dial indicator. Desired end play is 0.13-0.23 mm (0.005-0.009 inch) for LT1, 0.178-0.254 mm (0.007-0.010 inch) for LV1 or 0.229-0.305 mm (0.009-0.012 inch) for LV2.

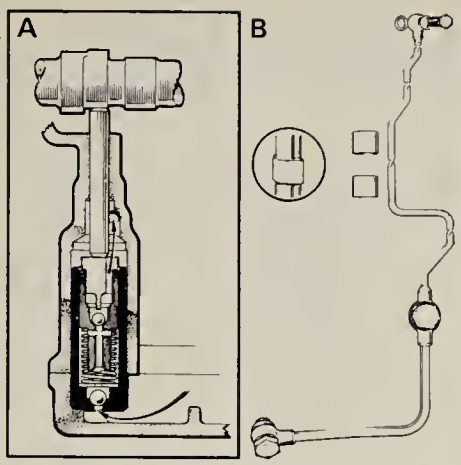


Fig. L16—A self-regulating plunger-type oil pump is used. An external pipe (B) carries oil to flywheel end main bearing and cylinder head. Gears, governor camshaft and underside of piston are splash lubricated.

End play is adjusted by installing shims (13–Fig. L12) between main bearing housing (14) and crankcase. Paper and metal shims are available. Note that paper shims must be installed between all metal surfaces for sealing purposes. Make certain the oil drain hole in main bearing housing is located at the bottom and protect oil seal lip when installing bearing housing. Heat crankshaft gear before reinstalling on crankshaft. Complete installation by reversing the removal procedure.

Fig. L17—To service oil pump, drain and carefully remove sump.

OIL PUMP

A self-regulating plunger type pump, operated by a push rod from the camshaft, is located in a drilling in the crankcase. Refer to Fig. L16. The pump is retained in the crankcase by the oil sump. The pump should deliver a minimum pressure of 70 kPa (10 psi) at 1000 rpm.

To service oil pump, drain oil and remove sump (Fig. L17). Withdraw oil pump assembly and renew if necessary.

LISTER

Model	No. Cyls.	Bore	Stroke	Displ.
ST1	1	95.25 mm (3.75 in.)	88.9 mm (3.50 in.)	0.63 liters (38.7 cu. in.)
ST2	2	95.25 mm (3.75 in.)	88.9 mm (3.50 in.)	1.27 liters (77.3 cu. in.)
ST3	3	95.25 mm (3.75 in.)	88.9 mm (3.50 in.)	1.90 liters (116 cu. in.)

Engines in this section are four-stroke, air-cooled type with vertical cylinders and direct fuel injection. Engine type can be indentified by the last two digits of engine number found on plate (Fig. L24) attached to fuel pump housing cover. Crankshaft rotation may be either clockwise or counterclockwise as viewed from flywheel end depending on engine build number.

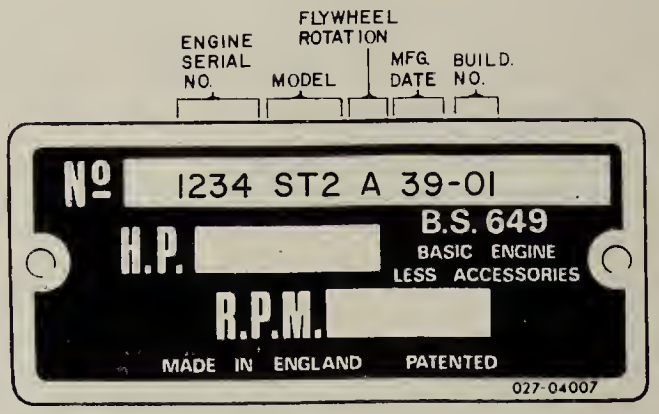


Fig. L24—View of typical engine identification plate. To ensure use of correct parts and specifications, use complete number.

MAINTENANCE

STARTING PROCEDURE

Engines may be equipped with either manual or electric start. In cases where final drive is from gear end, manual starting can be from flywheel end through a geared-up starter.

To start engine, pull control lever out and allow it to rotate to "Start" position. Move compression release levers toward flywheel. On engines equipped with variable speed control, move lever to "Fast" position. On manual start engines, lightly oil end of crank handle, then insert handle to crank engine. On all engines, crank engine slowly 3 to 20 turns to prime cylinders and lubrication system. After priming, crank engine until maximum speed is obtained and release compression release levers.

CAUTION: Do not allow crank handle to continue to rotate on running shaft.

When engine reaches normal speed, turn control lever to "Run" position and adjust speed as required.

NOTE: If engine is equipped with electric starter, do not crank engine more than 20 seconds at a time.

LUBRICATION

Under normal operating conditions, recommended engine oil is heavy-duty diesel lubricating oil that equals or exceeds API service classification CC. If engine is operated under heavy load and high temperature, or if sulfur content in fuel exceeds 0.6%, API service classification CD oil is recommended. However, manufacturer does not recommend using CD oil in new or reconditioned engines until after the first oil change or 250 hours of operation as lubricating characteristics of CD oil may inhibit running-in on engines operating under light load conditions.

Recommended oil change interval is every 250 hours of operation with filter change at the same time.

If operating temperatures fall below minus 15°C (5°F), SAE 5W oil should be used. For temperatures between minus 15°C (5°F) to 4°C (40°F) SAE 10W oil is recommended. From 4°C (40°F) to 30°C (85°F), use SAE 20W-20. Above 30°C (85°F), use SAE 30.

FUEL SYSTEM

Number 2 diesel fuel is recommended for most conditions. Number 1 diesel fuel should be used for light duty or cold weather operation.

FILTER AND BLEEDING. Manufacturer recommends renewing fuel filter after every 500 hours of operation. However, if engine indicates signs of fuel starvation (surging or loss of power), filter should be changed regardless of hours of operation. After servicing fuel filter, air must be bled from system in the following manner:

Make sure fuel tank is full. Loosen each bleeder valve (Fig. L26) one at a time on filter body and outlet banjo fitting. Retighten valves when air-free fuel flow is obtained. Loosen bleeder valve on each fuel pump (start nearest to fuel tank); tighten when air-free flow is obtained.

If engine fails to start at this point, loosen high pressure fuel line connections at injectors. With engine control lever in "Start" position, crank engine until fuel is discharged at loosened fittings. Retighten fuel line fittings and start engine.

INJECTION TIMING. A separate Bryce Berger fuel pump is used for each cylinder. It is recommended that all service of fuel pump(s), other than renewal, be carried out by an approved diesel injection service center.

To check injection pump timing, turn flywheel so "Z" mark (for cylinder/pump being checked) on flywheel is aligned with arrow on fan shroud. Refer to Fig. L27. Remove fuel pump delivery valve holder, delivery valve and spring. Reinstall delivery valve holder and set control lever in "Start" position. Turn crankshaft in opposite direction of normal rotation until fuel flows from delivery valve holder, then turn slowly in normal direction until fuel flow just stops. Beginning of injection occurs at this point and firing mark on flywheel

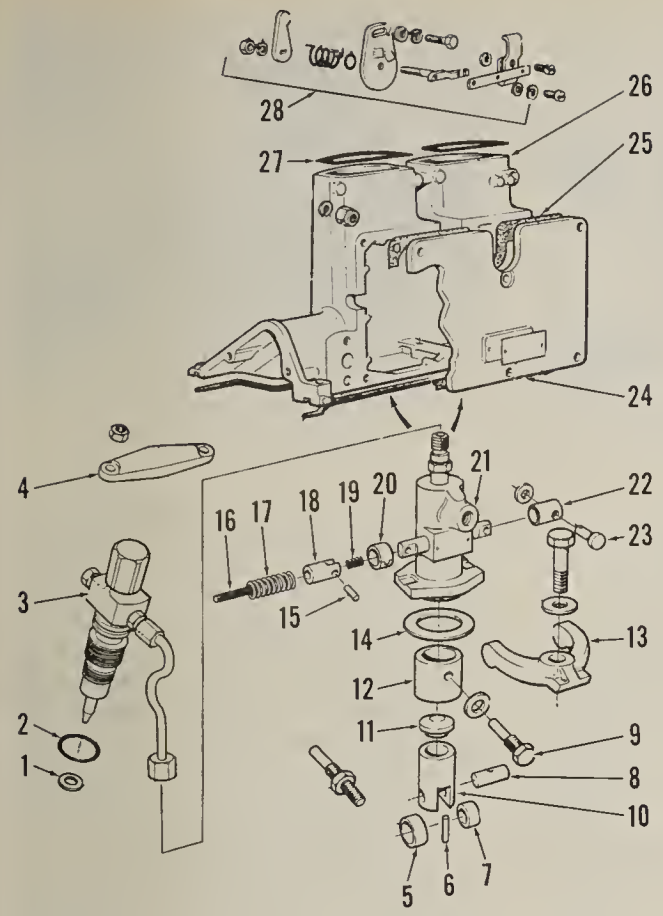


Fig. L25—Exploded view of typical fuel pump and housing assembly.

1. Injector gasket
2. Injector seal
3. Injector
4. Injector clamp
5. Roller
6. Retaining pin
7. Roller bushing
8. Roller pin
9. Tappet guide locating pin
10. Tappet
11. Tappet cap
12. Tappet guide
13. Fuel pump clamp
14. Shim
15. Pin
16. Fuel pump rod
17. Spring
18. Shackle
19. Spring
20. Spring clip
21. Fuel pump
22. Stop sleeve
23. Pin
24. Fuel pump housing cover
25. Gasket
26. Fuel pump housing
27. Gasket
28. Engine control assy.

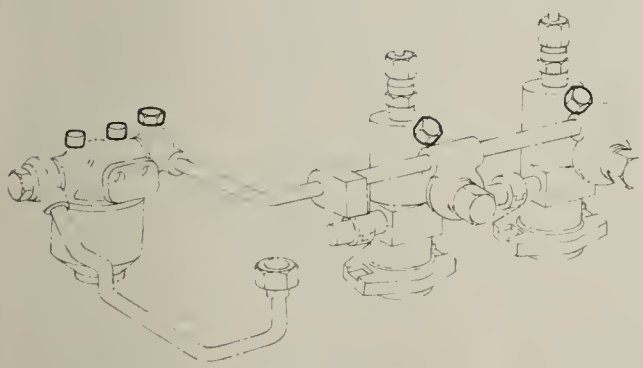


Fig. L26—When fuel filter is renewed, air must be bled from fuel system. Loosen each bleeder valve one at at time. Retighten valves as air is purged from system.

should be aligned with mark on fan shroud if timing is correct.

If timing marks are not aligned, change thickness of shims (14—Fig. L25) between pump body and crankcase as necessary. To advance timing, remove shims; to retard timing, add shims. After correct timing is obtained, reinstall delivery valve and spring. Tighten delivery valve holder to 54 N·m (40 ft.-lbs.) and pump mounting screws to 9 N·m (80 in.-lbs.).

On multiple-cylinder engines, turn flywheel to firing position for next cylinder and repeat procedure for each pump.

FUEL INJECTOR. All engines are equipped with injectors using four spray hole nozzles. Diameter of spray holes is 0.25 mm (0.010 inch). To check injector spray pattern, remove injector and reconnect externally to fuel pump.

WARNING: Fuel emerges from injector with sufficient force to penetrate the skin. When checking injector, keep yourself clear of nozzle spray.

Crank engine about 60 rpm. Spray should be a very fine mist. All sprays should have the same appearance and length. If one hole is blocked or if fuel dribbles from nozzle tip, injector must be renewed or cleaned and rebuilt by an authorized service department.

Injector opening pressure setting is 19250-20270 kPa (2790-2940 psi). The leak down rate, measured with a hand test pump and gage, must drop from 15200 to 10135 kPa (2205 to 1470 psi) within 10 to 55 seconds.

Fig. L27—When correctly timed, "Z" mark on flywheel should be aligned with mark on fan shroud at beginning of injection. View "A" is ST1 engine and View "B" is ST2 or ST3 engine.

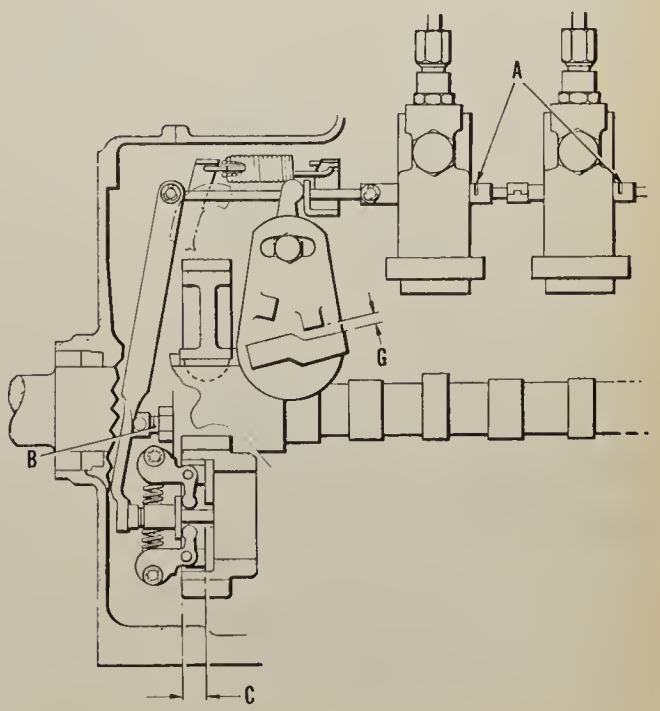


Fig. L28—View of fuel pump and governor settings. Refer to text for details and to Fig. L28A for value of (G).

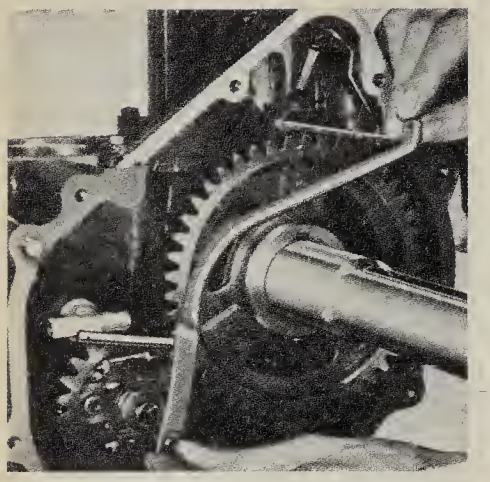


Fig. L29—Governor lever is carried in a fulcrum bearing in the crankcase.

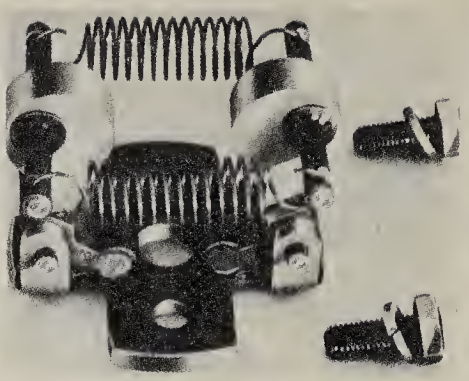


Fig. L31—View of constant speed governor weight assembly.

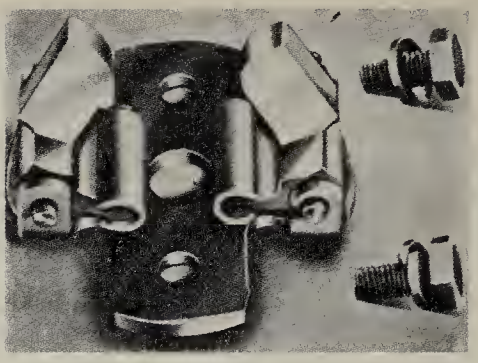


Fig. L32—Variable speed governor weight assembly used on ST engines.

GOVERNOR

Two types of flyweight governors are used: variable and constant speed. Governor assemblies are contained within the gear case. Governor weights and springs are serviced separately. To install correct weights and springs and adjust properly, contact an authorized service department.

Governor lever (Fig. L29) operating the fuel pump(s) is carried in a fulcrum bearing in the crankcase. The bearing extends approximately 19 mm (0.750 inch) from face of crankcase and is adjusted as follows:

Set engine control to "RUN" position and adjust linkage until calibration marks (A–Fig. L28) line up with sides of fuel pump bodies within 0.13 mm (0.005 inch). Pump racks must move freely after this adjustment. Adjust governor lever fulcrum (B) so that when calibration marks are in position, distance (C) is 12.7 mm (½-inch).

To set clearance (G–Fig. L28), maintain correct clearance and rotate locating plate until calibration marks (A) are in position. The full width of each mark must be visible. After making adjustments, pump racks and linkage must move freely.

The correct values of (G) are listed in Table 1.

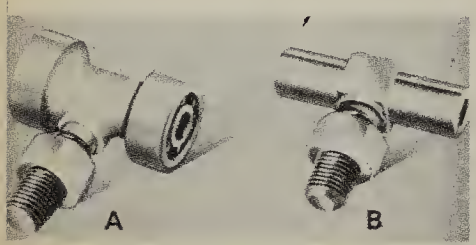


Fig. L30—Fulcrum bearing is fitted so bearing center line is approximately 19 mm (0.750 inch) from crankcase surface. Bearing (A) is used on three-cylinder engines; (B) is used on one- and two-cylinder engines.

REPAIRS

TIGHTENING TORQUES

Refer to the following table for special tightening torques. All fasteners are metric.

Connecting rod	43 N·m (32 ft.-lbs.)
Cylinder head	68 N·m (50 ft.-lbs.)
Crankshaft balance weights	43 N·m (32 ft.-lbs.)
Flywheel	405 N·m (300 ft.-lbs.)
Injector cap nut	88 N·m (65 ft.-lbs.)
Injector clamp	20 N·m (15 ft.-lbs.)
Rocker adjusting screw	20 N·m (15 ft.-lbs.)

VALVE ADJUSTMENT

To adjust valve clearance, turn crankshaft until piston for cylinder being adjusted is at top dead center on compression stroke (both rocker arms loose). Loosen locknut and turn rocker arm adjusting screw (11–Fig. L33) until appropriate size feeler gage can be inserted between rocker arm and valve stem end. Recommended clearance with engine cold is 0.15-0.20 mm (0.006-0.008 inch) for intake and exhaust. On multiple cylinder engines, repeat procedure for each cylinder. Manufacturer recommends checking valve clearance after every 500 hours of operation.

To adjust compression release mechanism, proceed as follows: On engines with an oil filler hole in cylinder head cover, compression release is adjusted through this opening. Turn crankshaft until piston is at top dead center on compression stroke. Move lever to actuate compression release. Loosen locknut and turn adjusting screw down until it touches the rocker arm, then turn screw down an additional ¾ turn and tighten locknut. Repeat procedure for each cylinder.

When no oil filler hole is provided, adjust release lever screw (with cover removed) until it just touches rocker arm when cover is reinstalled and release lever is operated. Then, remove

Table 1—Governor settings.

Engine Speed Rpm	Clearance "G"	Movement of Rack corresponding to clearance
1200 - 2199	0.35 - 0.41 mm (0.014 - 0.016 in.)	1.14 - 1.29 mm (0.045 - 0.051 in.)
2200 - 2699	0.66 - 0.71 mm (0.026 - 0.028 in.)	2.11 - 2.26 mm (0.083 - 0.089 in.)
2700 - 3000	0.89 - 0.94 mm (0.035 - 0.037 in.)	2.84 - 3.0 mm (0.112 - 0.089 in.)
For engines driving fans or centrifugal pumps and marine engines, set as follows:		
1200 - 2199	*0.08 - 0.13 mm (0.003 - 0.005 in.)	0.23 - 0.38 mm (0.009 - 0.015 in.)
2200 - 2699	0.15 - 0.20 mm (0.006 - 0.008 in.)	0.51 - 0.66 mm (0.020 - 0.026 in.)
2700 - 3000	0.38 - 0.43 mm (0.015 - 0.017 in.)	1.22 - 1.37 mm (0.048 - 0.054 in.)
* All moisture Extraction Units should be set to this clearance.		

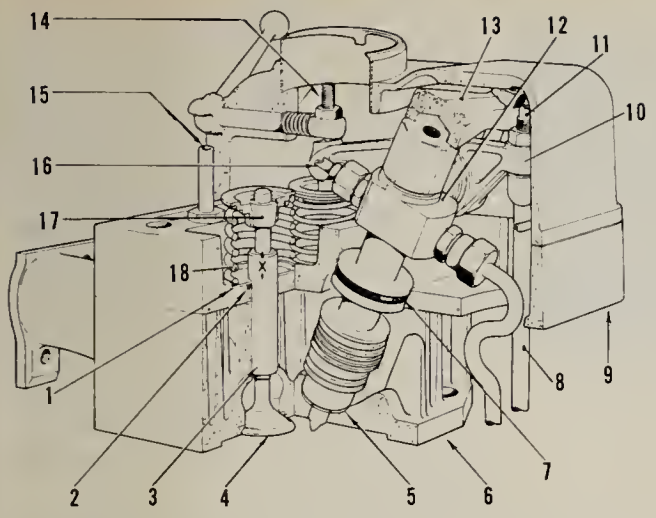


Fig. L33—Cross-sectional view of cylinder head assembly. When renewing valve guides, press in until top of guide extends 12.60-13.10 mm (0.495-0.515 inch) above surface of head (X).

1. Retaining plate
2. Valve guide seal
3. Intake valve guide
4. Intake valve
5. Injector gasket
6. Cylinder head
7. Injector seal
8. Push rod
9. Top plate
10. Rocker arm assy.
11. Rocker arm adjusting screw
12. Injector
13. Injector clamp
14. Compression release lever assy.
15. Breather tube
16. Leak-off pipe
17. Valve spring keepers
18. Valve spring

Fig. L34—When reinstalling piston, connecting rod and cylinder barrel, flat sided fins must face flywheel.

cover and turn screw down an additional ¾ turn.

After adjustment is completed, turn crankshaft by hand to make sure no interference exists between valve and piston when release lever is operated.

CYLINDER HEAD

A two-piece cylinder head is used. Top half (top plate) is cast iron and contains the valve gear and breather tube. Lower half is aluminum alloy and contains the valve seats. Valve guides are a press fit and hold the cylinder head halves together. Refer to Fig. L33.

Before removing cylinder heads, be sure to identify cylinder head position so heads can be reinstalled in their original location. As cylinder heads are removed, place shims and gasket from each cylinder with respective cylinder head for use in reassembly.

To check clearance between piston and cylinder head, place two pieces of soft lead wire 1.2 mm (0.048 inch) thick on head, clear of valves and as near as possible in line with piston pin. Hold wires in place with grease, then reinstall cylinder head and gasket. Tighten stud nuts evenly to specified torque, then crank piston past top dead center twice. Remove cylinder head and measure thickness of wire. Desired clearance is 0.89-0.97 mm (0.035-0.038 inch). To adjust clearance, install shims between cylinder head and head gasket.

During final assembly, a high melting point grease should be used to hold shims and head gasket in place. Apply grease sparingly and do not put grease on cylinder side of gasket. Manufacturer recommends that a thread sealer be used on cylinder head nuts, studs and area of top plate that contacts nuts. Before tightening cylinder head nuts on multiple cylinder engines, install the manifold or use a straightedge to ensure alignment of intake and exhaust ports. Then, tighten nuts evenly to 68 N·m (50 ft.-lbs.). Reinstall injectors after cylinder head nuts have been tightened. Complete installation by reversing the removal procedure.

VALVE SYSTEM

The valve guides are a press fit into the cylinder head. An "O" ring (2–Fig. L33) and retaining plate (1) are located around intake guide (3). Note that guides are not interchangeable. When installing new guides, use suitable tools and guide in from the top until top of guides extend 12.60-13.10 mm (0.495-0.515 inch) above surface of cylinder head casting. After guides are installed, check valve stem clearance in guide and ream guide if necessary. Desired operating clearance is 0.07-0.10 mm (0.003-0.004 inch). Wear limit is 0.13 mm (0.005 inch).

Valve face and seat angles are 45° for intake and exhaust. Desired seat width is 1.65-2.29 mm (0.065-0.090 inch) for intake and 1.35-1.78 mm (0.053-0.070 inch) for exhaust. With valve installed, top of intake valve should be 1.02-1.27 mm (0.040-0.050 inch) below combustion surface of cylinder head and exhaust valve should be 0.89-1.14 mm (0.035-0.045 inch) below head surface.

Rocker arm bushing bore should be 25.45-25.46 mm (1.0020-1.0025 inches) and rocker arm shaft diameter should be 25.36-25.37 mm (0.9985-0.9988 inch). Desired operating clearance is 0.08-0.10 mm (0.003-0.004 inch) with a wear limit of 0.20 mm (0.008 inch).

Intake and exhaust valve springs are identical. Spring free length should be 57.00-59.03 mm (2.244-2.324 inches). Renew valve springs if distorted, pitted or rusted.

PISTON, PIN, RINGS AND CYLINDER

The piston is equipped with five rings: one barrel faced, chrome, keystone type top ring; two tapered face compression rings; a spring expander type oil control ring above the piston pin and a slotted oil scraper ring below the piston pin. The full floating piston pin is retained in piston by two snap rings. The removable, cast iron cylinder is reborable for installation of oversize piston and rings.

When removing pistons and cylinders on multiple cylinder engines, mark cylinder number on piston, connecting rod and cylinder barrel. Components should be reinstalled in their original location if not renewed. To disassemble, remove cylinder head, air shields, crankcase side cover and lubricating oil pipes. Remove connecting rod cap, then rotate piston to TDC. Withdraw cylinder, piston and connecting rod as an assembly from crankcase. Retain all shims and gaskets with their respective cylinder for use in reassembly.

Thoroughly clean piston and cylinder, then check for scoring, wear and other damage. Piston standard diameter measured at bottom of skirt is 95.039-95.065 mm (3.7417-3.7427 inches) and standard cylinder bore is 95.27-95.30 mm (3.751-3.752 inches). Recommended clearance between piston skirt and cylinder is 0.211-0.262 mm (0.0083-0.0103 inch) with a wear limit of 0.35 mm (0.014 inch).

With piston ring positioned squarely in cylinder bore, measure ring end gap with feeler gage. Refer to the following table for recommended end gap dimensions.

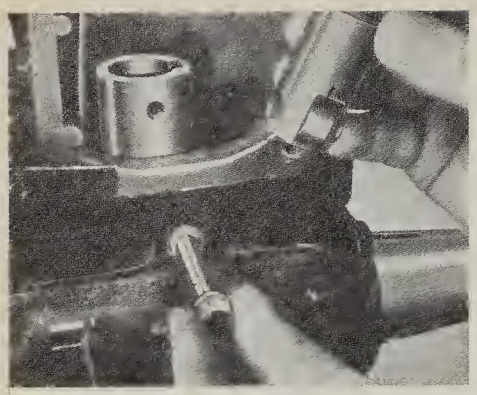


Fig. L35—To service camshaft, remove fuel pump(s), fuel pump tappet(s), tappet guide locating pin(s) and guide(s).

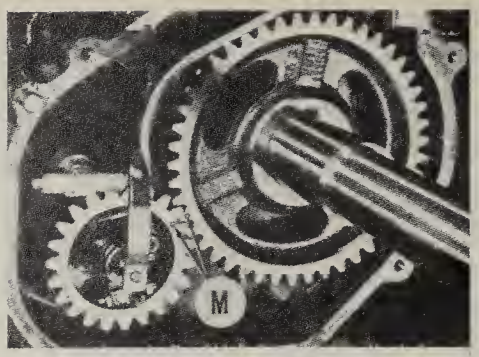


Fig. L37—Align timing marks (M) as shown when reinstalling timing gears.

Ring Gap	Desired	Maximum
Top	0.43-0.61 mm (0.017-0.024 in.)	0.89 mm (0.035 in.)
Compression	0.28-0.46 mm (0.011-0.018 in.)	0.76 mm (0.030 in.)
Scrapers	O.38-0.56 mm (0.015-0.022 in.)	0.76 mm (0.030 in.)

Piston pin diameter is 33.3324-33.3375 mm (1.3123-1.3125 inches). Recommended operating clearance in connecting rod bushing is 0.0435-0.0606 mm (0.0071-0.0024 inch) and maximum allowable clearance is 0.085 mm (0.0033 inch).

When reassembling, be sure piston is installed on connecting rod with the wording "CAMSHAFT SIDE" on top of piston on the same side as matching numbers stamped on connecting rod. One side of center compression rings is marked "TOP" and must be installed on piston accordingly. All other rings may be installed either side up. Lubricate piston and cylinder bore with clean oil, then install piston into cylinder. Assemble piston and cylinder to crankcase making certain cylinder is positioned with flat sided fins facing front and rear of engine and "CAMSHAFT SIDE" marking on piston is facing camshaft side of engine. Tighten connecting rod cap nuts to 43 N·m (32 ft.-lbs.).

CONNECTING ROD

The connecting rod is fitted with a bushing in the small end and a precision, insert type bearing in the big end.

Standard crankpin diameter is 63.487-63.500 mm (2.4995-2.500 inches). Recommended rod bearing clearance is 0.04-0.08 mm (0.0016-0.0032 inch) and maximum allowable clearance is 0.14 mm (0.0055 inch).

Piston pin diameter is 33.3324-33.3375 mm (1.3123-1.3125 inches) and bushing inner diameter is 33.881-33.393 mm (1.3142-1.3147 inches). Desired operating clearance is 0.0435-0.0606 mm (0.0017-0.0024 inch) and maximum allowable clearance is 0.085 mm (0.0033 inch).

Connecting rod and cap are marked with matching numbers. Make certain these numbers are on the same side and face camshaft side of engine. Tighten connecting rod cap nuts to 43 N·m (32 ft.-lbs.).

CAMSHAFT

To remove camshaft, first remove cylinder head, fuel pump housing cover, crankcase side cover and end cover. If equipped with engine mounted fuel tank, disconnect fuel lines and remove fuel tank assembly. Disconnect speeder spring. Remove fuel pump(s), fuel pump tappet(s), tappet guide locating pin and guide (Fig. L35). Set oil pump to bottom of its travel and depress pump return spring (Fig. L36) until pump push rod is below level of camshaft bearing. Hold cam followers up with suitable tools, then carefully withdraw camshaft assembly.

Inspect camshaft and bushings for excessive wear and other damage. Camshaft journal diameter is 44.34-44.35 mm (1.7455-1.746 inches). Bushing inside diameter at flywheel end is 44.49-44.51 mm (1.7515-1.7525 inches). Desired operating clearance is 0.14-0.15 mm (0.0055-0.006 inch) and maximum allowable clearance is 0.23 mm (0.009 inch). Inner diameter of all other bushings is 44.53-44.56 mm (1.753-1.7545 inches). Desired clearance is 0.18-0.23 mm (0.007-0.009 inch) and maximum allowable clearance is 0.28 mm (0.011 inch).

When renewing camshaft bushings, soak bushings in engine oil for four hours, prior to installation. Using suitable tools, install bushings with thinnest part of bearing wall (marked with an "O") towards the top.

When reinstalling camshaft, reverse the removal procedure. Be sure to align "O" timing marks (M – Fig. L37) on camshaft gear and crankshaft gear.

CRANKSHAFT AND BEARINGS

The crankshaft is supported at gear end by split main bearing located in the crankcase and at flywheel end by a split bearing located in main bearing housing. One intermediate bearing is used on ST2 engines and two intermediate bearings are used on ST3 engines. The in-

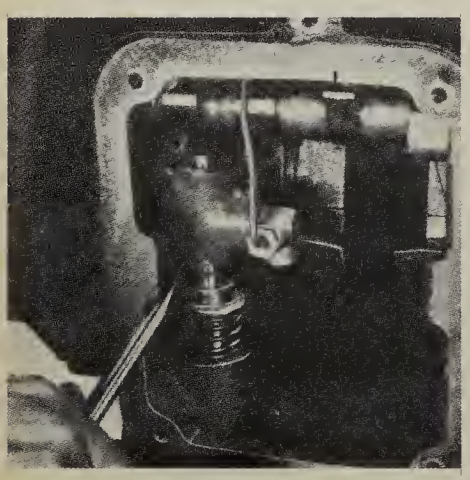
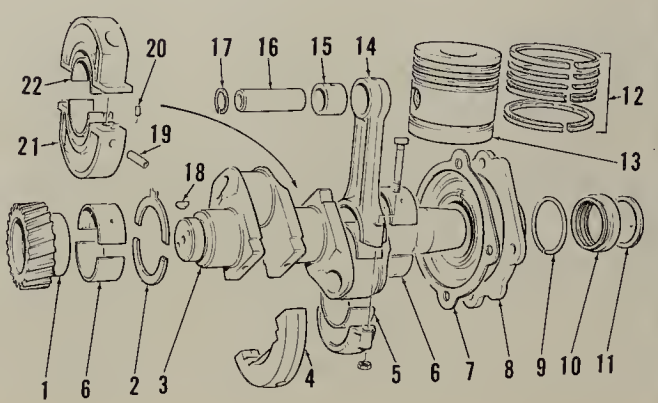


Fig. L36—To remove camshaft, set oil pump to bottom of its travel and depress pump return spring until pump push rod is below level of camshaft bushings.

Fig. L38—Exploded view of typical crankshaft, connecting rod and piston assembly.

1. Crankshaft gear
2. Split thrust washer
3. Crankshaft assy.
4. Balance weight
5. Rod bearings
6. Main bearings
7. Shim
8. Main bearing housing
9. Oil slinger
10. Oil seal
11. Felt
12. Piston rings (5)
13. Piston
14. Connecting rod
15. Piston pin bushing
16. Piston pin
17. Retainer
18. Key
19. Locating dowel
20. Dowel
21. Center main bearing housing
22. Center main bearing



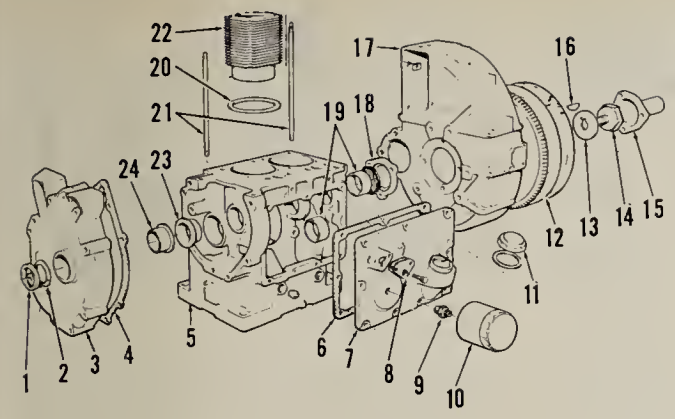


Fig. L39—Exploded view of typical crankcase assembly.

1. Oil seal
2. Oil slinger
3. End cover
4. End cover gasket
5. Crankcase assy.
6. Crankcase cover gasket
7. Crankcase cover
8. Plate
9. Union
10. Oil filter
11. Oil filler cap & seal
12. Flywheel assy.
13. Lockwasher
14. Flywheel retaining screw
15. Crankshaft extension
16. Key
17. Fan shroud
18. Camshaft end cover
19. Camshaft bushings
20. Cylinder barrel gasket
21. Cylinder studs
22. Cylinder barrel
23. Camshaft bushing
24. End cover bushing

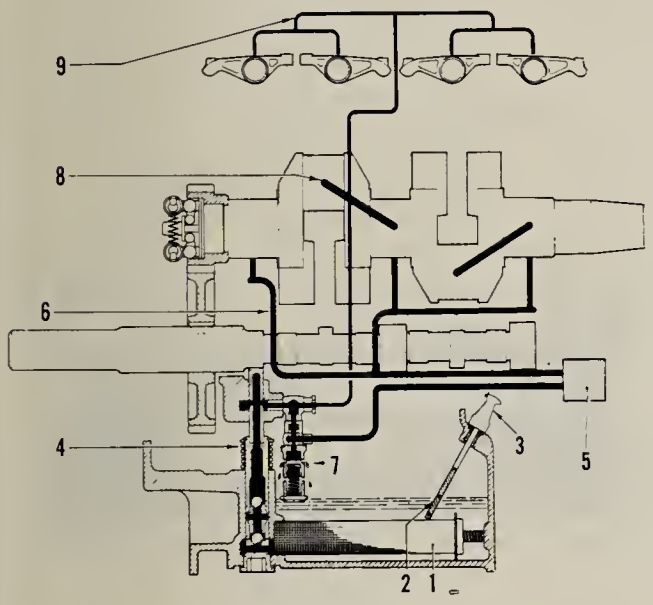


Fig. L40—Basic lubrication system on early model engines.

1. Screen
2. Oil level
3. Dipstick assy.
4. Oil pump assy.
5. Oil filter
6. Oil pipe to main bearings
7. Pressure relief valve
8. Oil passage to rod bearings
9. Oil pipe to rocker arms

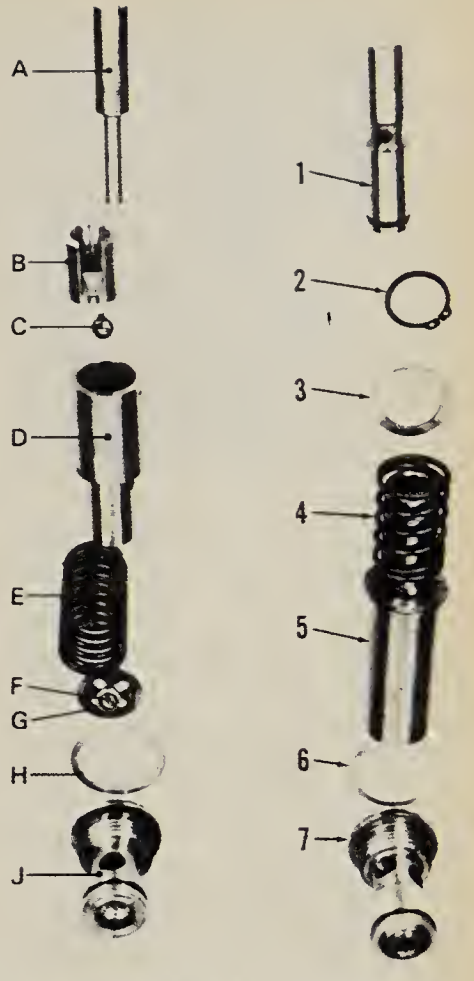


Fig. L41—A nonregulated oil pump (right) was used on early engines. The self-regulating pump (left) was introduced May 1978.

A. Push rod
B. Plunger cap
C. Ball valve
D. Plunger
E. Spring
F. Ball
G. Retaining plate
H. Washer
J. Plug

1. Push rod
2. Snap ring
3. Washer
4. Spring
5. Oil plunger assy.
6. Washer
7. Suction valve

termediate bearings are split type contained in a housing (21 – Fig. L38) which is located in crankcase by a hollow dowel (19). One end of dowel is threaded ¼ inch UNF so a bolt can be threaded into dowel for removal purposes.

End thrust is taken by split thrust washers at each end of crankshaft. Thickness of new thrust washers is 2.31-2.36 mm (0.091-0.093 inch).

Main journal standard diameter is 63.47-63.50 mm (2.4988-2.500 inches). Desired main bearing clearance is 0.04-0.09 mm (0.0016-0.0035 inch) and wear limit is 0.16 mm (0.006 inch). Crankpin diameter is 63.487-63.500 mm (2.4995-2.500 inches). Desired rod bearing clearance is 0.04-0.08 mm (0.0016-0.0032 inch) and maximum allowable clearance is 0.14 mm (0.0055 inch).

When reassembling, be sure main bearings are installed with oil groove to the top and oil holes are aligned. Copper face of thrust washers must face crankshaft. Use grease to hold washers in place during assembly. On multiple cylinder engines, intermediate bearing housings are marked on one side "FLYWHEEL END" and must be installed accordingly. Align locating dowel hole in bearing housing with corresponding hole in side of crankcase. Install dowel with threaded end outward. Install main bearing housing then check crankshaft end play. Recommended end play is 0.13-0.25 mm (0.005-0.010 inch) for ST1 and ST2 engines or 0.18-0.30 mm (0.007-0.012 inch) for ST3 engines and is adjusted using shims (7 – Fig. L38) between bearing housing and crankcase. Apply sealing compound to bearing housing and shims during final assembly and make certain oil drain hole in housing is to the bottom. If crankshaft balance weights were removed, reinstall weights using new cap screws and tighten to 43 N·m (32 ft.-lbs.). Heat crankshaft gear before installing. Be sure to align timing marks on crankshaft gear and camshaft gear (Fig. L37). Tighten flywheel mounting screw to 405 N·m (300 ft.-lbs.).

OIL PUMP

Two types of plunger oil pumps are used. Early model pump requires a separate pressure regulator (Fig. L40). The self-regulating pump (A through J – Fig. L41) was introduced in ST1 engines in May 1978. By end of 1978, all multi-cylinder engines were equipped with self-regulating pumps.

To service oil pump, drain crankcase oil. Remove crankcase door and turn engine until oil pump push rod is at its highest point. On early models, compress return spring and remove snap ring. Loosen and remove suction valve (early type) or pump plug (late type) from bottom of crankcase.

NOTE: Pump assembly is under spring tension and care should be taken to prevent loss or damage to pump parts.

Clean and inspect all parts and renew any showing excessive wear or other damage. Reassemble by reversing disassembly procedure.

LISTER

Model	No. Cyls.	Bore	Stroke	Displ.
TL2	2	98.42 mm (3.875 in.)	101.6 mm (4.0 in.)	155 cc (94.5 cu. in.)
TL3	3	98.42 mm (3.87 in.)	101.6 mm (4.0 mm)	232 cc (141.5 cu. in.)
TS1	1	95.25 mm (3.75 in.)	88.9 mm (3.50 in.)	63 cc (38.7 cu. in.)
TS2	2	95.25 mm (3.75 in.)	88.9 mm (3.50 in.)	127 cc (77.3 cu. in.)
TS3	3	95.25 mm (3.75 in.)	88.9 mm (3.50 in.)	190 cc (116 cu. in.)

Engines in this section are four-stroke, air-cooled type with vertical cylinders and direct fuel injection. "TL" engines use a belt driven axial flow fan to provide cooling air flow while the flywheel serves as the cooling fan on "TS" engines. Engine type can be identified by the last two digits (build number) of engine number found on plate attached to the manifold air cowl (Fig. L50). Standard crankshaft rotation is counterclockwise as viewed from flywheel end.

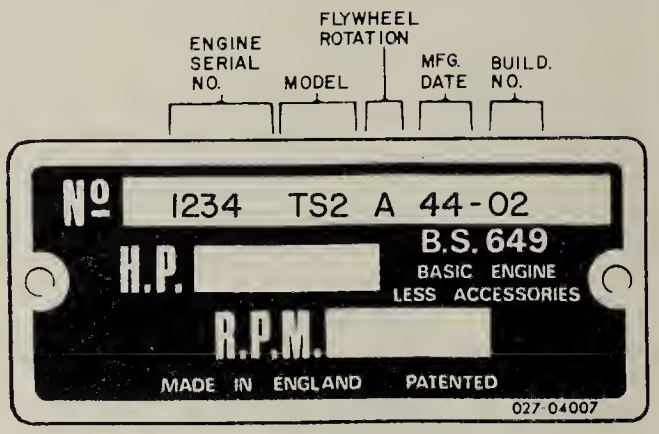


Fig. L50—View of typical engine identification plate. To ensure use of proper parts and specifications, use complete number.

MAINTENANCE

STARTING PROCEDURE

Before starting, check fuel and oil levels. Move engine control to "start" and set variable speed control (if equipped) to "fast" position. On "TS" engines, actuate compression release lever to relieve compression pressure. On manual start engines, lightly oil end of crank handle, then insert handle to crank engine. On "TS" engines, crank engine until maximum speed is obtained and release compression release lever. On manual start engines, remove crank handle immediately when engine fires. On electric start engines, crank engine with starter motor until engine fires. On variable speed engines, adjust speed as required.

NOTE: If engine is equipped with electric starter, do not crank engine more than 20 seconds at a time.

LUBRICATION

Under normal operating conditions, recommended engine oil is heavy-duty diesel lubricating oil that equals or exceeds API service classification CC. If

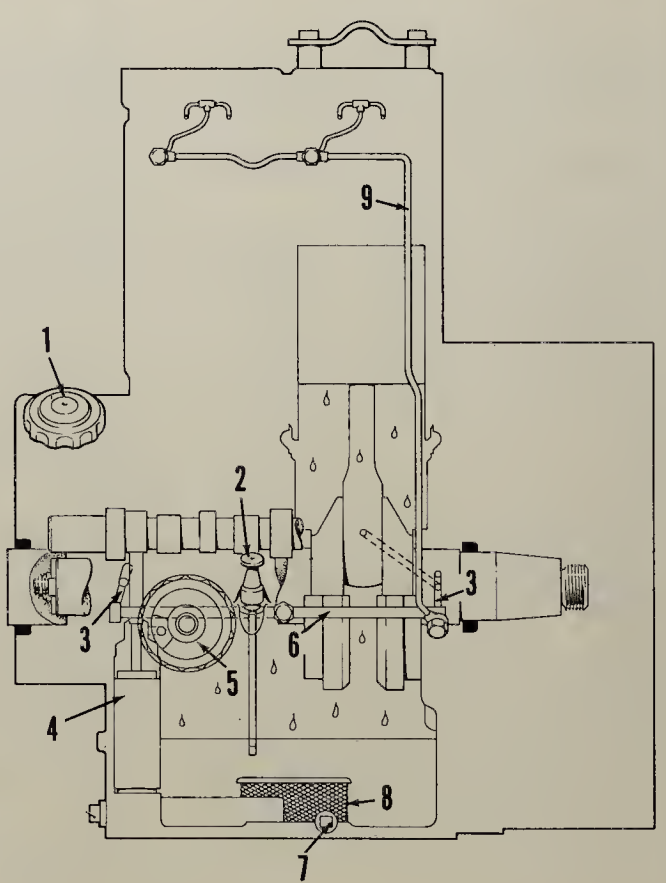


Fig. L51—Basic lubrication system used on all models. An external pipe (9) supplies oil to valve train.

1. Filler cap
2. Dipstick
3. Oil passage drillings
4. Oil pump
5. Oil filter
6. Oil gallery
7. Drain plug
8. Pickup screen
9. Oil pipe to valve train

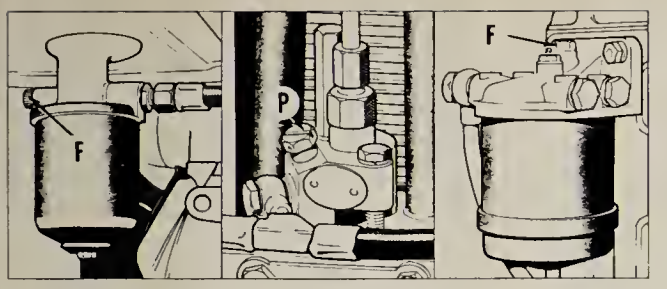


Fig. L52 – When fuel filter is serviced, air must be bled from system. Loosen each bleeder screw one at a time. Retighten screws when air-free fuel flow is obtained.

engine is operated under continual heavy load and high temperature, or if sulfur content in fuel exceeds 0.6%, API service classification CD oil is recommended. However, manufacturer does not recommend using CD oil in new or reconditioned engines until after first oil change or 25 hours of operation as lubricating characteristics of CD oil may inhibit running-in on engines operating under light load conditions. Multigrade oil that meets MIL-L-2104B or MIL-L-2104C specifications may be used but is not approved for use in heavy-duty applications.

Recommended oil change interval is every 250 hours of operation with filter change at the same time. Oil filler opening is on timing gear end cover. Check oil level with dipstick; do not overfill.

If operating temperatures fall below minus 15°C (5°F), SAE 5W oil should be used. From minus 15°C (5°F) to 4°C (40°F), use SAE 10W. For temperatures between 4°C (40°F) and 30°C (85°F), SAE 20W-2 is recommended. Above 30°C (85°F) use SAE 30.

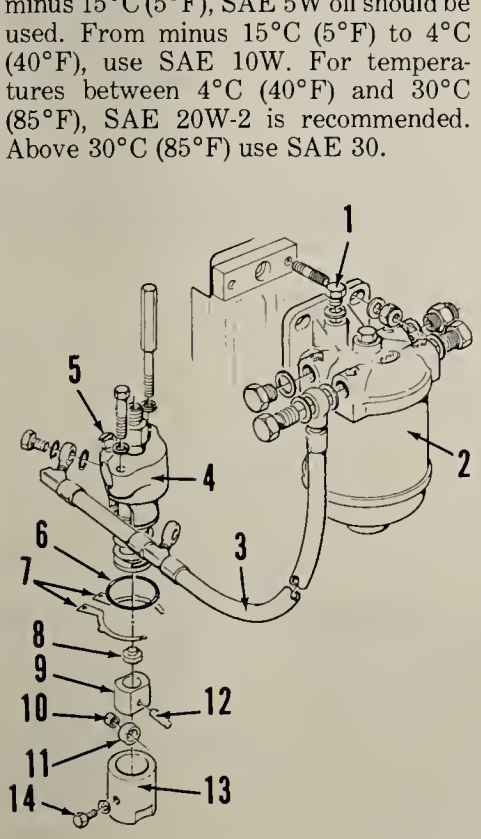


Fig. L53 – Partially exploded view of fuel pump and filter assembly.

1. Bleed screw
2. Fuel filter assy.
3. Fuel inlet hose
4. Injection pump
5. Bleed screw
6. "O" ring
7. Split shims
8. Tappet insert
9. Fuel pump tappet
10. Bushing
11. Roller
12. Pin
13. Tappet guide
14. Locating screw

All engines are full pressure lubricated. Refer to Fig. L51 for view of lubrication system components.

FUEL SYSTEM

Number 2 diesel fuel is recommended for most operating conditions. Number 1 diesel fuel may be used for light duty or cold weather operation.

FILTER AND BLEEDING. Some engines are equipped with a fuel filter assembly attached to bottom of fuel tank while other engines have a cartridge type filter assembly mounted on flywheel end of engine. Manufacturer recommends renewing fuel filter after every 500 hours of operation. However, if engine indicates signs of fuel starvation (surging or loss of power), filter should be renewed regardless of hours of operation. After servicing fuel filter, air must be bled from system as outlined in the following paragraph.

Make sure fuel tank is full. Loosen bleed screw (F – Fig. L52) on filter housing. Retighten screw when fuel flows from bleeder. Loosen bleed screw (P) on fuel pumps one at a time (starting nearest fuel filter), then retighten screw when fuel flow is obtained. If engine fails to start at this point, loosen high pressure fuel line connections at injectors. With engine control lever in "start" position, crank engine until fuel is discharged at loosened fittings. Retighten fuel line fittings and start engine.

Fig. L55 – To check injection pump timing, rotate crankshaft until timing mark on flywheel for cylinder/pump being checked is aligned with arrow on flywheel housing. Beginning of injection should occur at this point.

INJECTION TIMING. A separate Bryce Berger fuel pump is used for each cylinder. Fuel pumps are located on side of engine between push rods and are actuated by lobes on the engine camshaft. Split type pump mounting shims (7 – Fig. L53) are used to adjust injection timing.

To check injection timing, turn the flywheel to the firing position for the cylinder/pump being checked and align timing mark on flywheel with arrow in window of flywheel housing (Fig. L55). Remove fuel injector pipe from pump. Remove delivery valve holder (1 – Fig. L54), delivery valve (3) and spring (2), then reinstall delivery valve holder. Place control lever in "run" position. Turn crankshaft in opposite direction of normal rotation until fuel flows from delivery valve holder, then turn crankshaft slowly in normal direction until fuel flow just stops. At this position beginning of injection occurs and firing

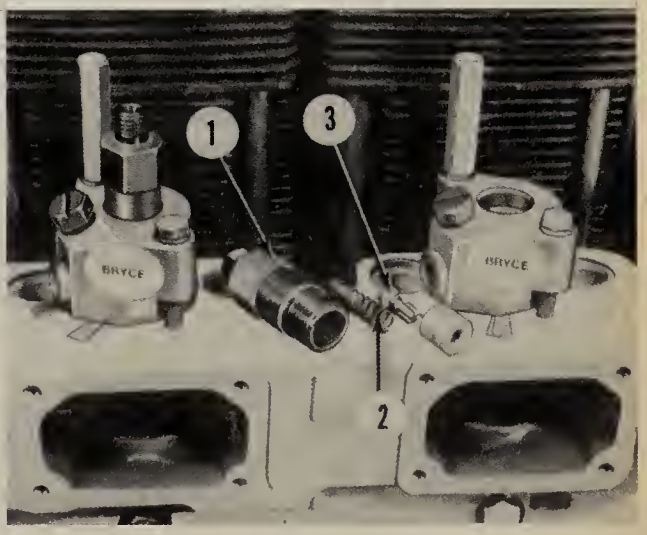


Fig. L54 – Pump delivery valve (3) and spring (2) must be removed when checking injection timing. Delivery valve holder (1) is reinstalled during timing operation. Refer to text.

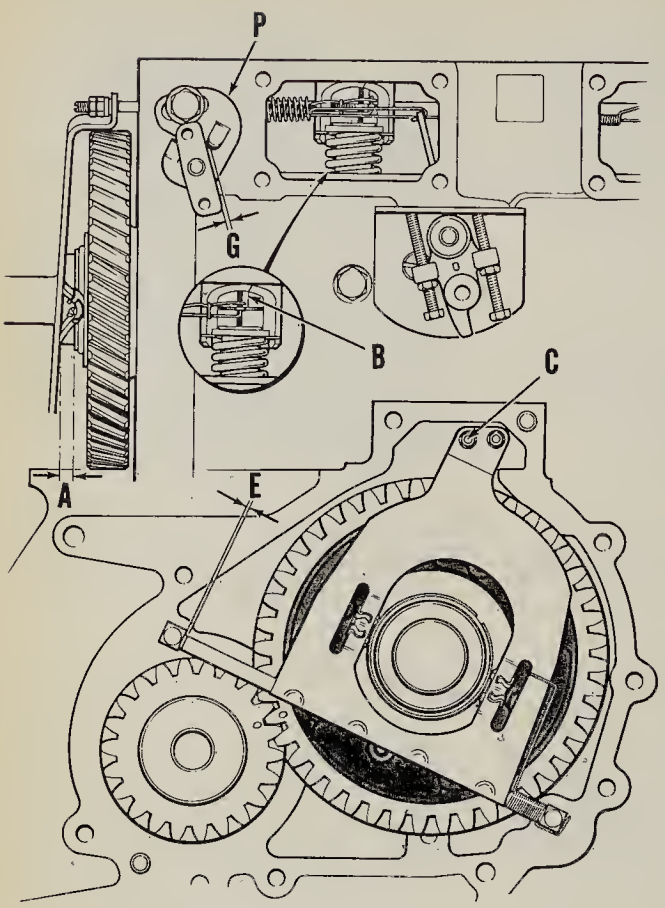


Fig. L56—To check and adjust fuel pump and governor linkage, remove fuel pump inspection covers and timing gear end cover. Refer to text for details.

mark on flywheel should be aligned with arrow on flywheel housing if timing is correct.

If timing marks are not aligned, add or remove shims between pump body and crankcase as necessary. To advance timing, remove shims; to retard timing, add shims. After correct timing is obtained, reinstall delivery valve and tighten delivery valve holder to 54 N·m (40 ft.-lbs.).

Turn flywheel to firing position for the next cylinder and repeat timing procedure for each pump.

GOVERNOR

To check or adjust governor settings, first remove injection pump inspection covers and timing gear end cover. Engine control should be in "start" position and camshaft tapped gently towards flywheel to remove any end play.

Check governor lever end play (E–Fig. L56) and install shims, if necessary, to obtain end play of 0.12-0.025 mm (0.005-0.010 inch).

Clearance (A) between thrust sleeve and step on camshaft should be 5.0 mm (0.197 inch) with fuel pump calibration mark (B) aligned with mark on center of number 1 fuel pump (number 1 cylinder is nearest gear end of engine). Adjust by changing the length of governor link (C) by turning locknuts. Then, adjust length of governor link between each fuel pump until calibration marks (B) on all pumps are aligned.

Set engine control lever to "run" position. Loosen control lever plate (P) retaining screw and insert a feeler gage between control lever and stop equal to recommended clearance (G) as listed in the following table. While maintaining clearance (G), rotate control lever plate until fuel pump calibration marks (B) are aligned. Clearance (G) settings are shown for various engine rated speeds. If engine is rated for a different speed, use the value for the nearest higher speed.

"TL" Engines

Engine Speed Rpm	Clearance "G"
1500	0.6 mm (0.024 in.)
1800	0.6 mm (0.024 in.)
3000	1.25 mm (0.050 in.)

"TS" Engines

1500	0.6 mm (0.025 in.)
1800	0.6 mm (0.024 in.)
2500	0.8 mm (0.032 in.)
3000	1.00 mm (0.040 in.)

Engines may be equipped with either a constant speed or variable speed control. Turning adjusting screw (5C–Fig. L57) clockwise will increase speed on a constant speed engine. The other screw has no function on constant speed engines.

Screw (5V) is used to adjust low idle speed on variable speed engines. To adjust, turn screw counterclockwise until

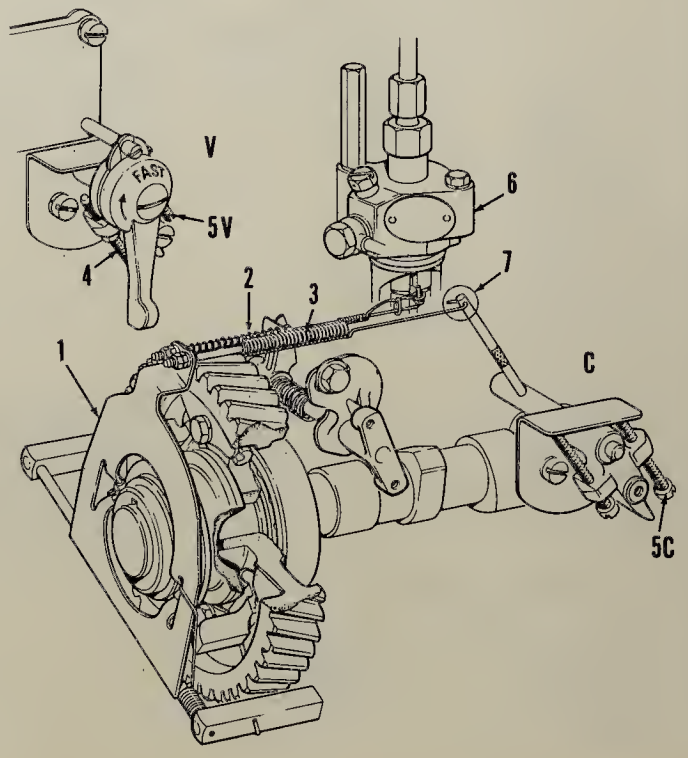


Fig. L57—A constant speed (C) or variable speed control (V) may be used. Refer to text for engine speed adjustment procedure. Be sure speeder spring (3) is connected properly through hole in spindle as shown at (7).

1. Governor lever
2. Governor link
3. Speeder spring
4. Maximum speed screw (variable)
5C. Speed adjusting screw (constant)
5V. Idle speed screw (variable)
6. Fuel pump
7. Speeder ring connection

it no longer affects engine speed and governor causes engine to "hunt". Turn screw clockwise until "hunting" is eliminated and desired idle speed is obtained, then tighten locknut.

The lower screw (4) is used to limit the maximum speed on variable speed engines. Turning the screw clockwise reduces maximum speed and turning the screw out (counterclockwise) will increase maximum speed.

Governor weights and springs are serviced separately. For proper parts identification and adjustment, contact an authorized service department.

REPAIRS

TIGHTENING TORQUES

Refer to the following table for tightening torques. All fasteners are metric.

Connecting rod	43 N·m (32 ft.-lbs.)
Cylinder head	68 N·m (50 ft.-lbs.)
Flywheel:	
TL engines	610 N·m (450 ft.-lbs.)
TS engines	475 N·m (350 ft.-lbs.)
Injection pump	9 N·m (80 in.-lbs.)
Injector clamp	21 N·m (15 ft.-lbs.)
Injector pipe nuts	28 N·m (21 ft.-lbs.)
Main bearing housing	27 N·m (20 ft.-lbs.)
Manifold nuts (lower)	9 N·m (80 in.-lbs.)
Manifold nuts (upper)	21 N·m (15 ft.-lbs.)
Oil sump	27 N·m (20 ft.-lbs.)

VALVE ADJUSTMENT

To adjust valve clearance, first remove cylinder head cover. Turn crankshaft until piston is at TDC on compression stroke (both valves closed). Loosen locknut and turn rocker arm adjusting screw (29–Fig. L58) until appropriate size feeler gage can be inserted between rocker arm and valve stem end. Recommended clearance with engine cold is 0.15-0.20 mm (0.006-0.008 inch) for intake and exhaust. Repeat procedure for remaining cylinders. Firing order for three-cylinder engines is 1-2-3. Manufacturer recommends adjusting valve clearance after every 250 hours or operation until clearances remain constant. Then, adjustment interval can be increased to every 1000 hours of operation.

To adjust compression release mechanism (on engines so equipped), turn crankshaft until piston is at TDC on compression stroke for cylinder being adjusted. Loosen adjuster locknut. Move lever to actuate compression release. Turn adjusting screw (24) until valve rocker just begins to depress valve, then turn screw one additional turn. Tighten locknut. Repeat procedure for all cylinders.

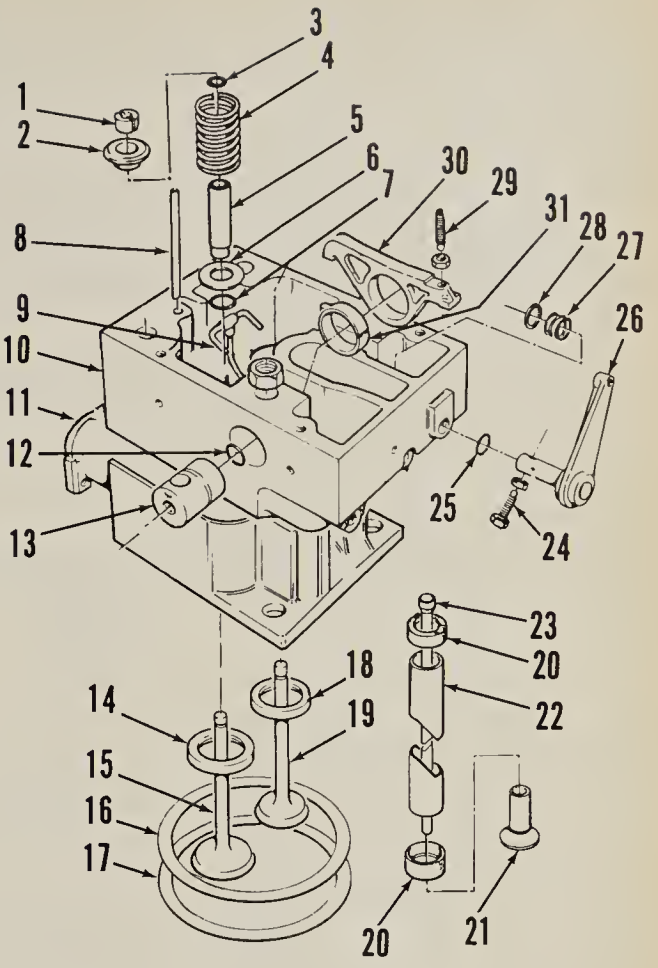


Fig. L58—Exploded view of cylinder head assembly. Compression release (24 through 28) is not used on TL2 and TL3 engines.

1. Valve keepers
2. Spring retainer
3. Seal ring (intake)
4. Valve spring
5. Valve guide
6. Plate (intake)
7. "O" ring (intake)
8. Breather tube
9. Oil pipe
10. Cylinder head (upper)
11. Cylinder head (lower)
12. "O" ring
13. Rocker stub shaft
14. Valve seat insert
15. Intake valve
16. Shim
17. Head gasket
18. Valve seat insert
19. Exhaust valve
20. Seal
21. Tappet
22. Push rod tube
23. Push rod
24. Adjusting screw
25. Seal ring
26. Compression release lever
27. Spring
28. Washer
29. Adjusting screw
30. Rocker arm
31. Bushing

CYLINDER HEAD

A two-piece cylinder head is used. Top half (top plate) is cast iron and contains the valve gear and breather tube. Lower half is aluminum alloy and contains the valve seat inserts. Valve guides are a press fit and hold the cylinder head halves together.

Before removing cylinder heads, be sure to identify cylinder head position (number 1 is at gear end of engine) so they can be reinstalled in their original positions. Note position of air baffles for correct reassembly. As cylinder heads are removed, place shims and gasket from each cylinder with respective cylinder head for use in reassembly.

To check piston-to-cylinder head clearance, place two pieces of soft lead wire 1.2 mm (0.048 inch) thick on head, clear of valves and as near as possible in line with piston pin. Hold wires in place with grease, then reinstall cylinder head with head gasket. Tighten stud nuts evenly to 68 N·m (50 ft.-lbs.), then crank piston past TDC twice. Remove cylinder head and measure thickness of wire. Desired clearance is 0.889-0.965 mm (0.035-0.038 inch). To adjust clearance, install shims (16–Fig. L58) between cylinder head and gasket (17).

During final assembly, a high melting point grease should be used to hold shims and head gasket in place. Use grease sparingly and do not apply grease on cylinder side of gasket. Manufacturer recommends that a thread sealer be used on cylinder head nuts, studs and area of top plate in contact with nuts. Install nuts with grade symbol facing upward. Before tightening cylinder head nuts on multiple cylinder engines, install manifold or use a straightedge to ensure alignment of intake and exhaust ports. Then, tighten nuts evenly to 68 N·m (50 ft.-lbs.). Reinstall injectors after cylinder head nuts have been tightened. Complete installation by reversing the removal procedure.

VALVE SYSTEM

The valve guides are a press fit into the cylinder head halves. An "O" ring (7 – Fig. L58) and retaining plate (6) are located around top of intake guide. When renewing intake guide, "O" ring must be inserted into the top plate recess before pressing guide into head. Note that guides are marked "IN TOP" and "EX TOP" and must be installed accordingly with lettering at the top. Apply sealer to outside of guides, then use suitable tools to press in guides until top of exhaust guide extends 17.40-17.90 mm (0.685-0.704 inch) above top plate surface and top of intake guide extends 12.40-12.90 mm (0.488-0.507 inch). After guides are installed, check valve stem clearance in guide and ream guide if necessary. Desired operating clearance is 0.07-0.10 mm (0.003-0.004 inch). Wear limit is 0.13 mm (0.005 inch).

All engines are equipped with renewable valve seat inserts for intake and exhaust. When renewing inserts, manufacturer recommends heating cylinder head to 120°C (250°F) and chilling inserts in dry ice before pressing insert into cylinder head counterbore.

Valve face and seat angles are 45° for intake and exhaust. Desired seat width is 1.65-2.29 mm (0.065-0.090 inch) for intake and 1.35-1.78 mm (0.053-0.070 inch) for exhaust. Top of intake valve should be recessed 1.02-1.27 mm (0.040-0.050 inch) below combustion surface of head and top of exhaust valve should be recessed 0.89-1.14 mm (0.035-0.045 inch).

The end of rocker stub shaft (13) is drilled and tapped M8 x 1.25. Shaft may be withdrawn using a suitable slide hammer. Outer diameter of shaft is 25.436-25.444 mm (1.0014-1.0017 inch) while inner diameter of rocker bushing (31) should be 25.462-25.475 mm (1.0025-1.0029 inch). Clearance when new is 0.018-0.039 mm (0.0007-0.0015 inch) and wear limit is 0.07 mm (0.003 inch). When reinstalling shaft, be sure the mark "TOP" on end of shaft is positioned accordingly and make certain "O" ring (12) is properly positioned.

Intake and exhaust valve springs are identical. Spring free length should be approximately 52 mm (2.047 inches) and minimum allowable length is 50.44 mm (1.986 inches). Renew spring if distorted or otherwise damaged.

INJECTOR

To remove injector, first thoroughly clean fuel lines and surrounding area. Remove cylinder head cover. Disconnect and remove fuel lines. Plug all openings to prevent entrance of dirt. Unscrew injector clamp screw, then withdraw injector and seal washer.

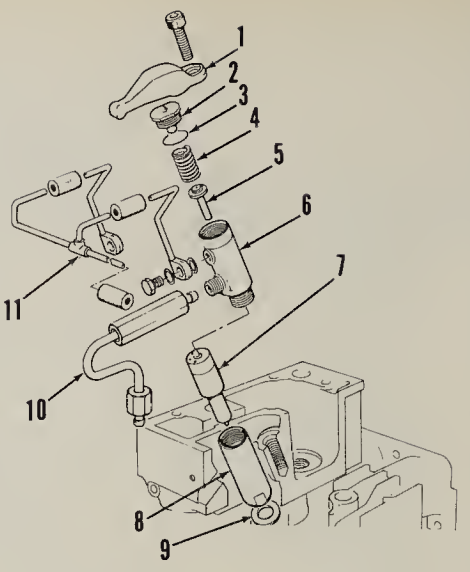


Fig. L59 – Exploded view of fuel injector assembly.

1. Injector clamp
2. Top plug
3. Seal ring
4. Spring
5. Push rod
6. Body
7. Nozzle valve assy.
8. Nozzle cut
9. Seal washer
10. Fuel pressure pipe
11. Fuel return pipe

When reinstalling injector, renew copper seal washer (9 – Fig. L59). Tighten retainer clamp (1) screw to 21 N·m (15 ft.-lbs.).

WARNING: Fuel leaves the injector nozzle with sufficient force to penetrate the skin. When testing, keep yourself clear of nozzle spray.

To check injector nozzle, connect to a hand test pump and operate tester lever a few quick strokes to purge air from nozzle and to make sure nozzle is not stuck. Then, operate test pump slowly while observing tester gage. Nozzle opening pressure should be 19250-20265 kPa (2790-2940 psi).

The injector nozzle has four spray holes each 0.25 mm (0.010 inch) diameter for "TS" engines or 0.28 mm (0.011 inch) for "TL" engines. Spray pattern should be symmetrical. If pattern is uneven with one or more sprays shorter than the others, spray holes are partially blocked and should be cleaned for best performance. If one hole is totally blocked or if fuel dribbles from nozzle tip, injector should be overhauled or renewed.

If injector is diassembled, do not use wire brush, emery cloth or hard metal tools to clean injector. If more than one injector is disassembled at the same time, keep parts from each injector separated as they are not interchangeable. Nozzle spray holes may be cleaned by inserting a cleaning wire slightly smaller in diameter than the orifice hole diameter. Be sure nozzle pintle slides freely in nozzle valve (7). If pintle sticks, reclean or renew nozzle valve assembly.

When reassembling injector, rinse all parts in clean diesel fuel and assemble while wet. Tighten injector top plug (2) to 27 N·m (20 ft.-lbs.). Retest injector as previously outlined.

INJECTION PUMP

Refer to Fig. L53 for a partially exploded view of fuel injection pump. To remove injection pump, first shut off fuel supply or drain fuel tank. Remove fuel supply pipe and injector pipe from pump. Remove injection pump inspection hole cover, then disconnect speeder spring and governor link. Remove pump mounting cap screws. Lift out injection pump making sure timing adjusting shims (7 – Fig. L53) are retained for use in reassembly.

It is recommended that injection pump be tested and serviced by a shop qualified in diesel fuel injection repair.

When reinstalling pump, be sure to renew "O" ring (6) and reinstall original shim pack (7). Pump mounting screw with larger head should be positioned closest to cylinder. Tighten pump mounting screws to 9 N·m (80 in.-lbs.). Complete installation by reversing removal procedure. Check injection timing and bleed air from system as outlined in MAINTENANCE section.

PISTON, PISTON PIN, RINGS AND CYLINDER

An aluminum alloy piston with a recessed combustion chamber in the crown is used on all engines. Pistons are equipped with two compression rings, a spring expander type oil scraper ring fitted above the piston pin and a slotted oil scraper ring fitted below piston pin on TL2 and TL3 engines. On all other engines, piston is equipped with three compression rings, a spring expander oil scraper ring above the piston pin and a slotted oil scraper ring below the piston pin.

When removing pistons and cylinders, be sure to identify air deflector shields so they can be properly reinstalled. Mark piston and cylinder position in relation to crankcase and number (number one cylinder is nearest gear end of engine) so they can be reinstalled correctly. Retain all shims and gaskets with their respective cylinder for use in reassembly.

Thoroughly clean piston and cylinder barrel and check for scoring, wear or other damage. For "TL" engines, piston diameter measured at bottom of skirt should be 98.219-98.244 mm (3.8669-3.8679 inches) and cylinder bore measured at bottom of piston travel area should be 98.425-98.450 mm

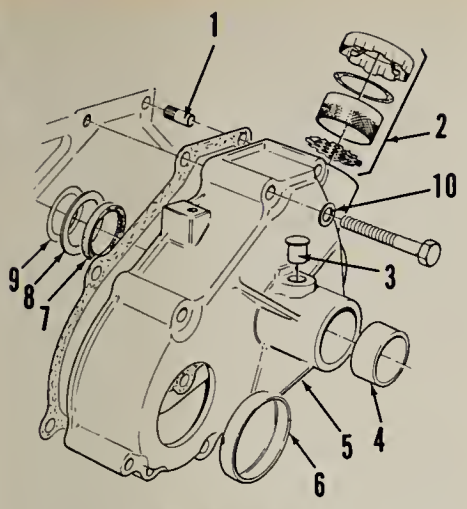


Fig. L60—Exploded view of end cover assembly used on "TS" engines. Bushing (4) is used to support starter crank handle on manual start engines. Thrust washer (8) controls camshaft end play.

1. Dowel
2. Oil filler assy.
3. Plastic plug
4. Bushing
5. End cover
6. Expansion plug
7. Oil seal
8. Thrust washer
9. Shim
10. Copper washer

(3.8750-3.8760 inches). Desired piston skirt-to-cylinder clearance is 0.181-0.231 mm (0.007-0.009 inch) with a wear limit of 0.32 mm (0.013 inch). For "TS" engines, piston diameter measured at bottom of skirt should be 95.039-95.065 mm (3.7417-3.7427 inches) and cylinder bore measured at bottom of piston travel area should be 95.27-95.30 mm (3.751-3.752 inches). Desired clearance between piston skirt and cylinder bore is 0.211-0.262 mm (0.008-0.010 inch) with a wear limit of 0.35 mm (0.014 inch).

Piston ring groove wear should be checked by measuring side clearance between top of ring and top of groove. On all engines, top ring groove is a keystone type and a special gage is needed to measure groove wear. All other ring grooves are rectangular and side clearance may be checked with a feeler gage. On "TL" engines, recommended side clearance for second compression ring is 0.08-0.13 mm (0.003-0.005 inch) and wear limit is 0.18 mm (0.007 inch). Side clearance for both oil scraper rings should be 0.05-0.10 mm (0.002-0.004 inch) and wear limit is 0.15 mm (0.006 inch). On "TS" engines, recommended side clearance for second and third compression rings is 0.13-0.18 mm (0.005-0.007 inch) and wear limit is 0.23 mm (0.009 inch). Side clearance for both oil scraper rings should be 0.05-0.10 mm (0.002-0.004 inch) while maximum allowable clearance is 0.15 mm (0.006 inch).

Piston ring end gap may be checked by inserting ring squarely into cylinder bore, then use a feeler gage to measure gap. Refer to the following table for specified end gap dimensions.

Ring End Gap—"TL" Engines

Top compression:
Desired.....0.30-0.57 mm (0.012-0.022 in.)
Maximum.....0.85 mm (0.033 in.)

Intermediate compression:
Desired.....0.20-0.47 mm (0.008-0.018 in.)
Maximum.....0.75 mm (0.029 in.)

Oil scraper:
Desired.....0.25-0.52 mm (0.010-0.020 in.)
Maximum.....0.80 mm (0.031 in.)

Ring End Gap—"TS" Engines

Top compression:
Desired.....0.41-070 N·m (0.016-0.027 in.)
Maximum.....0.98 mm (0.038 in.)

Intermediate compression:
Desired.....0.26-0.55 mm (0.010-0.021 in.)
Maximum.....0.85 mm (0.033 in.)

Oil scraper:
Desired.....0.36-0.65 mm (0.014-0.025 in.)
Maximum.....0.85 mm (0.033 in.)

Piston pin diameter should be 33.3324-33.75 mm (1.3123-1.3125 inches) for all engines. Desired operating clearance in rod small end bushing is 0.0435-0.0606 mm (0.0017-0.0024 inch) while maximum allowable clearance is 0.085 mm (0.0033 inch).

When reassembling, be sure piston is installed with the wording "CAMSHAFT SIDE" on top of piston on the same side as the raised dots on connecting rod. Intermediate compression ring or rings are tapered face rings and must be installed on piston with side marked "TOP" towards top of piston. All other rings may be installed either side up. Stagger piston ring end gaps 90° from each other. Lubricate piston and cylinder bore with clean oil, then install piston into cylinder. Install cylinder and piston assembly making certain deeper fins of cylinder face camshaft and manifold side of engine and "CAMSHAFT SIDE" marking on piston is properly positioned. Tighten connecting rod cap screws to 43 N·m (32 ft.-lbs.). Complete installation by reversing the removal procedure.

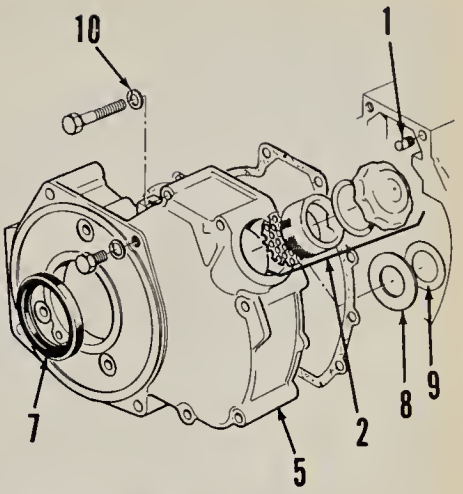


Fig. L61—Exploded view of end cover used on "TL" engines. Refer to Fig. L60 for component identification.

CONNECTING ROD

A forged steel connecting rod is used with a precision, insert type bearing in the big end and a bushing in the small end.

Standard crankpin diameter is 63.487-63.500 mm (2.4995-2.500 inches). Recommended rod bearing operating clearance is 0.04-0.08 mm (0.0016-0.0031 inch) and maximum allowable clearance is 0.14 mm (0.0055 inch).

Desired clearance for piston pin in small end bushing is 0.0435-0.0606 mm (0.0017-0.0024 inch) and maximum allowable clearance is 0.085 mm (0.0033 inch).

Tighten connecting rod cap screws to a torque of 43 N·m (32 ft.-lbs.).

END COVER

The end cover (5—Fig. L60 or L61) is located on gear end of crankcase with two dowels (1) and is secured by seven cap screws with copper seal washers.

To remove end cover on "TL" engines, first remove cooling fan drive belt and crankshaft pulley. Remove cap screws securing end cover to crankcase and axial flow fan to fan shroud, then withdraw end cover and fan as an assembly. Unbolt and remove fan housing from end cover if necessary.

To remove end cover on "TS" engines, remove plug (3—Fig. L60) from end cover. On manual start engines, rotate camshaft until spring pin (18—Fig. L63) is visible through hole in cover. Drive spring pin out, then turn camshaft 90° and tap crank handle catch pin (17) out of shaft. Unbolt and withdraw end cover.

Inspect oil seal (7—Fig. L60 or L61) and renew if necessary. Be sure to lubricate oil seal lip with grease and pro-

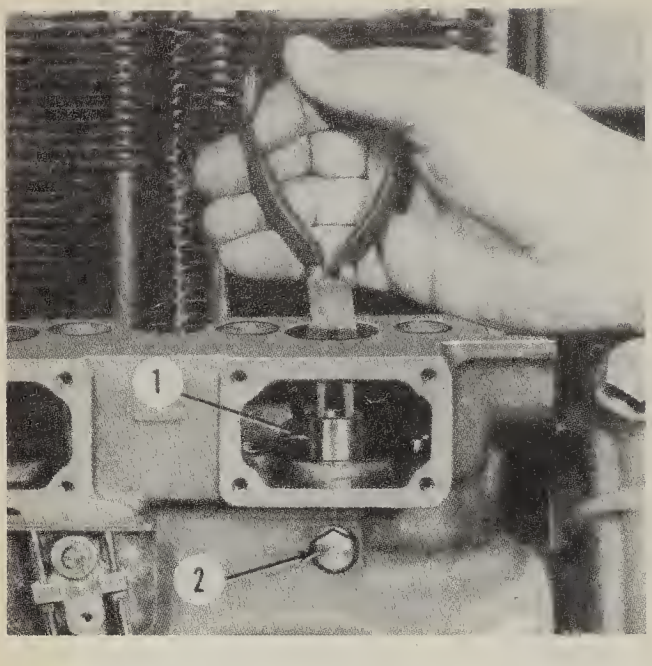


Fig. L62—Fuel injection pump tappets (1) and tappet guide locating screws (2) must be removed prior to removing camshaft.

tect seal lip during reassembly. Camshaft end play is controlled by thrust washer (8) and shim (9). Refer to CAMSHAFT paragraphs for end play adjustment procedure. Be sure to install copper seal washers (10) on cover mounting cap screws.

GOVERNOR

The governor assembly is mounted on the front of camshaft drive gear. To service governor, first remove end cover as previously outlined. Remove fuel pump inspection covers, then disconnect speeder spring and governor links at fuel pumps. Remove governor lever pivot pins (6—Fig. L63) and shims (8). Remove governor lever (9) assembly. Remove governor sleeve (14) with thrust washers (12) and pad (13). Remove governor weight retainers (5), pivot pins (3) and weights (4).

Inspect all parts for excessive wear and other damage and renew if necessary.

To reinstall governor, reverse the removal procedure while noting the following items. Be sure governor sleeve (14) is installed with thrust washer assembly facing outward. Be sure governor lever pivot pins (6) are installed with drilled end facing outward. Install shims (8) to provide governor lever end play of 0.12-0.25 mm (0.005-0.010 inch). Be sure speeder spring is reconnected as shown (7—Fig. L57). Refer to MAINTENANCE section for governor check and adjustment procedure.

CAMSHAFT AND CAM FOLLOWERS

The camshaft is supported by a ball bearing at the gear end and by bushings in the crankcase at the center and flywheel end. The camshaft operates the valves, oil pump, fuel injection pumps and fuel transfer pump (if so equipped). The governor weights are carried in the camshaft drive gear.

To remove camshaft, first remove cylinder heads and push rods, end cover, governor and fuel pumps. Remove oil sump and withdraw oil pump and push rod. Remove fuel pump tappets (1—Fig. L62). Remove tappet guide locating screws (2), then withdraw tappet guides. Move cam followers away from camshaft and hold in that position using suitable magnetic tools or clips. Carefully withdraw camshaft assembly from crankcase. Remove cam followers keeping them separated in order of removal so they can be reinstalled in their original positions.

To remove camshaft drive gear and ball bearing, drive spring pin (15—Fig. L63) into camshaft until it bottoms. Press gear (2) off camshaft and remove Woodruff key. Press bearing (1) off shaft. Drive spring pin out of camshaft.

Inspect camshaft, cam followers and cam bushings for scoring, wear and other damage. To renew camshaft bushings, the flywheel, flywheel housing, main bearing housing and alternator housing must first be removed.

Camshaft bearing journal diameter should be 44.34-44.35 mm (1.7457-1.7460 inches). Center bushing inside diameter should be 44.53-44.56 mm (1.7532-1.7543 inches). Desired operating clearance is 0.18-0.23 mm (0.007-0.009 inch) and maximum allowable clearance is 0.28 mm (0.011 inch). Flywheel end bushing bore should be 44.49-44.51 mm (1.7516-1.7524 inches). Desired operating clearance is 0.14-0.15 mm (0.0055-0.0060 inch) while wear limit is 0.23 mm (0.009 inch).

Camshaft bushings should be soaked in engine oil for four hours before being installed in engine. Special tools are

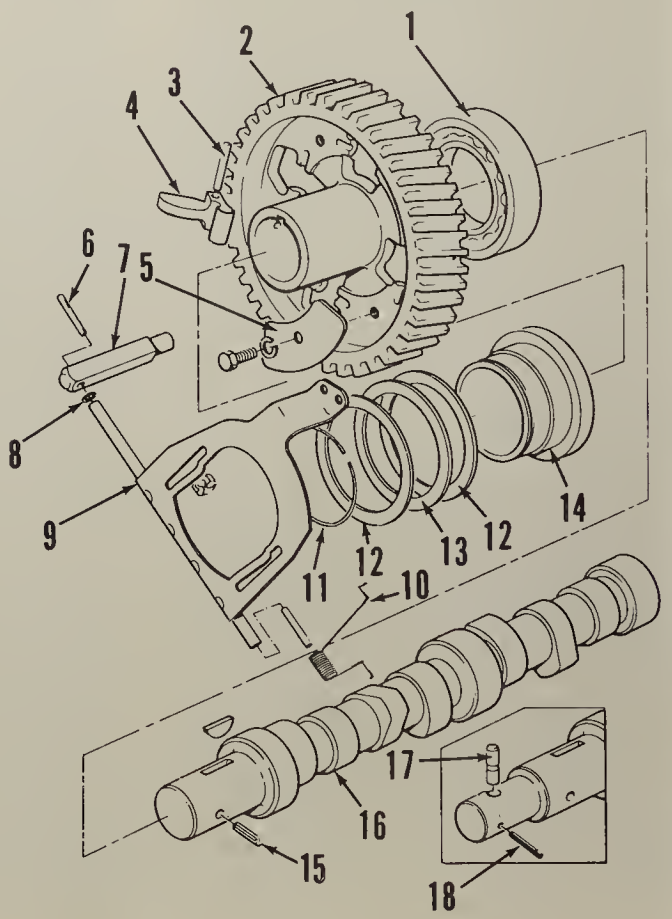


Fig. L63—Exploded view of camshaft and governor assembly. Catch pin (17) and spring pin (18) are used on manual start "TS" engines.

1. Ball bearing
2. Camshaft gear
3. Pivot pin
4. Governor weight
5. Weight retainer
6. Pivot pin
7. Pivot support bracket
8. Shim
9. Governor lever
10. Spring
11. Retaining ring
12. Thrust washers
13. Thrust pad
14. Governor sleeve
15. Spring pin
16. Camshaft
17. Catch pin
18. Spring pin

available from manufacturer to properly remove and install bushings. Install new bushings with thinnest section of bearing wall (marked "O") towards the top. Apply sealer to recess in crankcase before installing new expansion plug.

When installing camshaft drive gear, be sure to apply force against hub of gear only. Drive spring pin in until end of pin is approximately 1 mm (0.039 inch) below surface of gear hub. Make certain gear hub is free of burrs or nicks which would affect operation of governor thrust sleeve.

To reinstall camshaft, first insert cam followers and support them in a raised position. Lubricate cam lobes and bearing journals, then insert camshaft making sure "O" marks (Fig. L64) on camshaft gear and crankshaft gear are aligned. Reinstall thrust sleeve, governor, shim, thrust washer and end cover. Camshaft end play is controlled by thrust washer (8–Fig. L60 or L61) and shim (9). Use a dial indicator to measure end play. On engines where camshaft does not extend externally, measure through top right-hand tapped hole in end cover. With dial indicator rod against camshaft gear, insert a rod through fuel pump inspection opening and move camshaft back and forth. Recommended end play is 0.08-0.20 mm (0.003-0.008 inch). Shims (9) are available in different thicknesses to adjust end play, however, only one shim of appropriate thickness must be used. Complete installation by reversing the removal procedure.

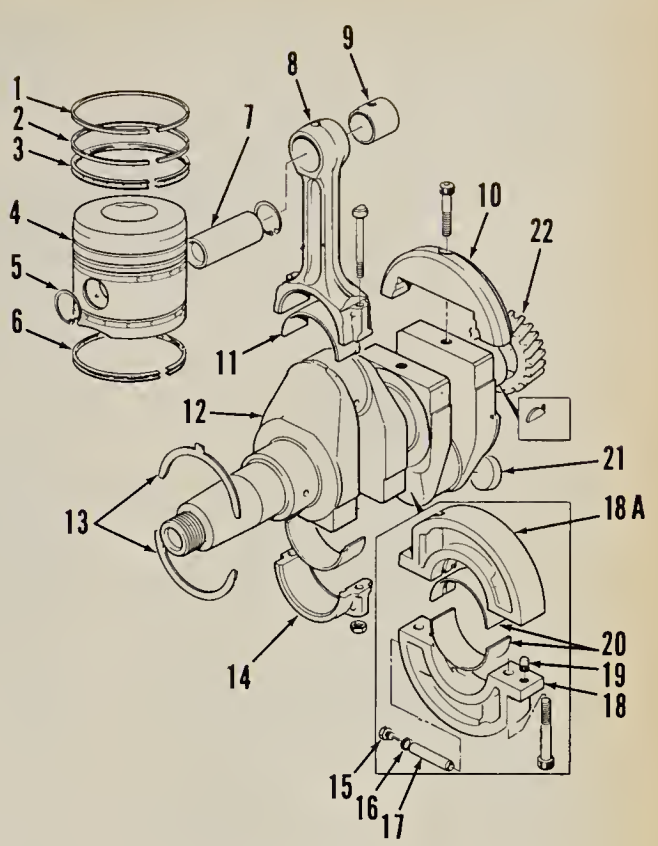


Fig. L65—Exploded view of crankshaft, connecting rod and piston assembly. Some engines use set screws in place of expansion plug (21) to plug oil passage drillings.

1. Top compression ring
2. Intermediate compression ring
3. Oil scraper ring
4. Piston
5. Snap ring
6. Oil scraper ring
7. Piston pin
8. Connecting rod
9. Bushing
10. Balance weight
11. Rod bearing insert
12. Crankshaft
13. Thrust washer
14. Connecting rod cap
15. Locating dowel plug
16. Copper washer
17. Locating dowel
18. Center main bearing housing (lower)
18A. Center main bearing housing (upper)
19. Dowel
20. Main bearing insert
21. Expansion plug
22. Crankshaft gear

CRANKSHAFT AND MAIN BEARINGS

The crankshaft is supported by main bearings located in crankcase at gear end and in the main bearing housing at flywheel end. Additional center main bearing is located in a bearing housing mounted in center of crankcase. Main bearings are two-piece, precision insert type bearing. Crankshaft end thrust is taken on copper-faced, split thrust washers at each end of crankcase.

To remove crankshaft, remove cylinder heads, oil sump, pistons and rods, end cover, camshaft, flywheel and flywheel housing. Remove center bearing housing locating dowel (17–Fig. L65) by threading a cap screw into end of dowel and pull dowel from crankcase. Leave screw in end of dowel to ensure dowel will be reinstalled correct end first. Remove cap screws securing main bearing end housing and remove alternator adapter. Screw two M6 bolts into threaded jackscrew holes in main bearing housing to remove housing. Retain shims with bearing housing for use in reassembly. Use a suitable puller to remove gear (22) from crankshaft. Mark position of center bearing housing in relation to crankcase to ensure correct reassembly. Remove crankshaft balance weights (10), then carefully remove crankshaft assembly from crankcase. Unbolt and remove center bearing housing from crankshaft.

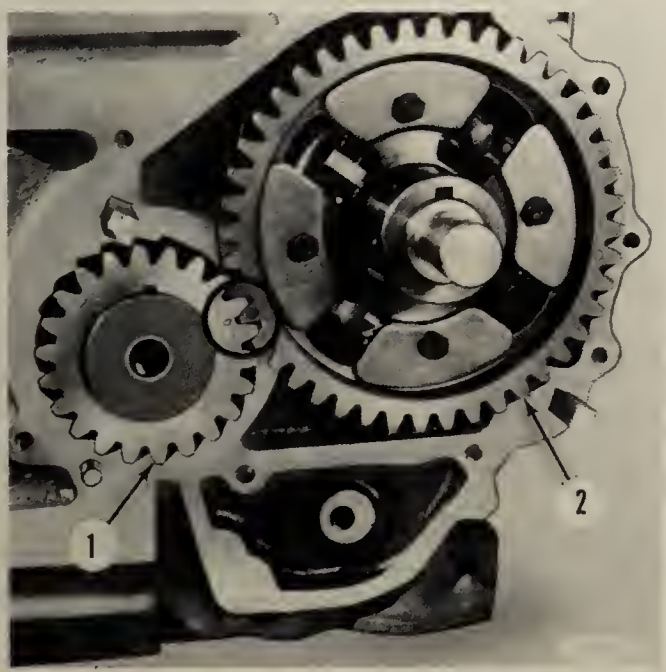


Fig. L64—When reinstalling camshaft, make certain timing marks "O" on camshaft gear (2) and crankshaft gear (1) are aligned.

Inspect crankshaft and bearings for excessive wear and other damage. If bearing failure has occurred, be sure oil passages in crankshaft are clean before reassembling.

A bushing removal and installation tool is available from manufacturer for use in properly renewing main bearing inserts. Crankshaft main bearing journal diameter when new is 63.47-63.50 mm (2.4988-2.500 inches). Recommended main bearing operating clearance is 0.04-0.09 mm (0.0016-0.0035 inch) and maximum allowable clearance is 0.16 mm (0.006 inch). Main bearings are two-piece inserts and are not interchangeable. Top half of bearing has an oil groove and hole which must be

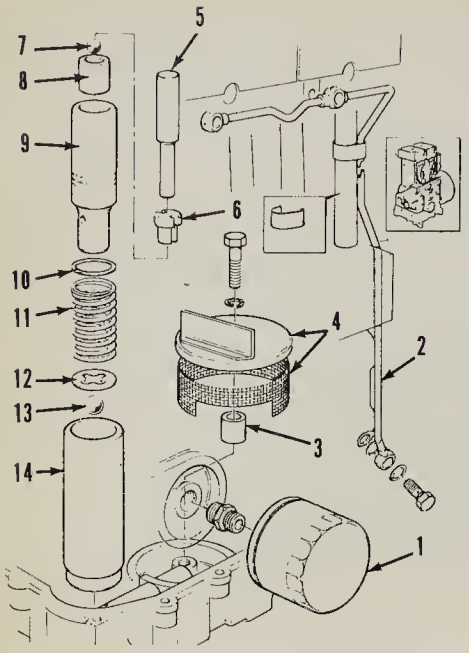


Fig. L66 – Exploded view of engine oil pump and lubrication system components.

1. Oil filter
2. Oil line to valve train
3. Spacer
4. Oil pickup strainer
5. Push rod
6. Plunger cap
7. Check valve ball
8. Valve seat
9. Plunger
10. Washer
11. Spring
12. Retaining plate
13. Check ball
14. Pump body

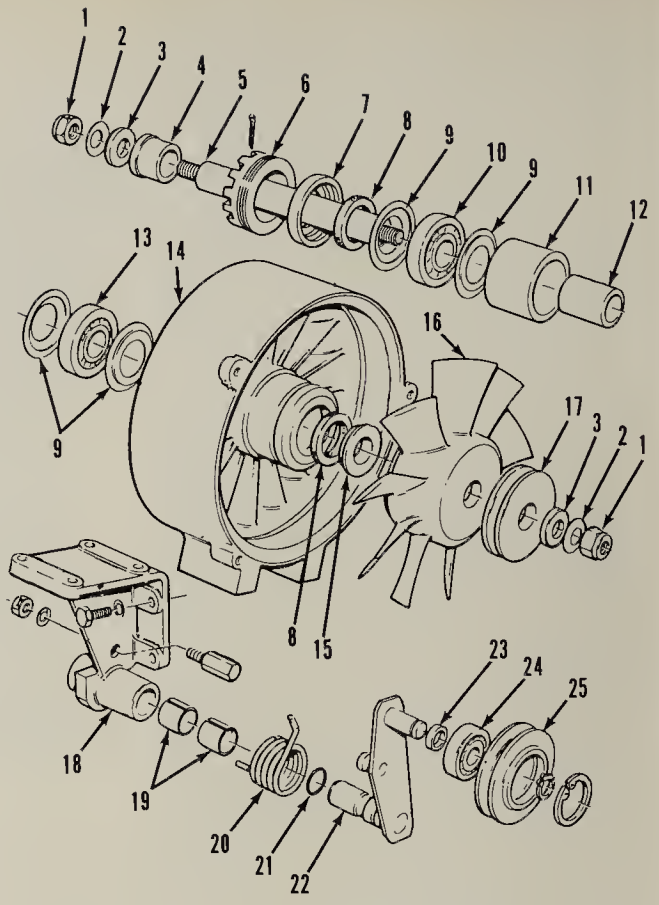


Fig. L67—Exploded view of axial flow cooling fan and belt tensioner used on TL2 and TL3 engines.

1. Nut
2. Spring washer
3. Flat washer
4. Seal bushing
5. Fan shaft
6. Nut
7. Seal carrier
8. Felt seal
9. Grease shield
10. Ball bearing
11. Outer spacer
12. Inner spacer
13. Roller bearing
14. Fan housing
15. Seal bushing
16. Fan
17. Pulley
18. Mounting bracket
19. Bushings
20. Tension spring
21. "O" ring
22. Idler arm
23. Spacer
24. Bearing
25. Idler pulley

properly aligned. Undersize bearings are available.

Crankpin diameter should be 63.487-63.500 mm (2.4995-2.500 inches). Desired rod bearing clearance is 0.04-0.08 mm (0.0016-0.0031 inch) while wear limit clearance is 0.14 mm (0.0055 inch).

Crankshaft end thrust is taken by copper-faced thrust washers located at both ends of crankshaft. Thickness of new thrust washer is 2.31-2.36 mm (0.091-0.093 inch).

When reinstalling crankshaft, note that center bearing housing is marked "FLYWHEEL END" and must be installed accordingly. Apply grease to gear end thrust washers to hold them in place. Make sure tab of upper washer is correctly located and copper face is towards crankshaft. Carefully insert crankshaft through front bearing and align match marks on center bearing housing and crankcase made during disassembly. Be sure hole for alignment dowel is aligned. To prevent damage to dowel, do not install until crankshaft oil seal and gear have been installed. Reinstall balance weights (10) making sure part numbers on weights face each other. Tighten balance weight mounting screws to 57 N·m (42 ft.-lbs.) on TL2 and TL3 engines or 68 N·m (50 ft.-lbs.) on all other engines. Use grease to hold thrust washers in place in main bearing housing. Make certain grooved bearing half is installed in top of bearing housing and oil supply holes are aligned. Reinstall main bearing housing with original shim pack but without oil seal. Use two bolts to secure housing, then position a dial indicator against end of crankshaft and check end play. Desired end play is 0.229-0.305 mm (0.009-0.012 inch). End play is adjusted by adding or removing bearing housing mounting shims. Install alternator adapter and tighten bearing housing cap screws to 27 N·m (20 ft.-lbs.). Heat crankshaft gear before reinstalling on crankshaft. Be sure to align "O" marks (Fig. L64) on camshaft gear and crankshaft gear. Install center bearing housing alignment dowel. Complete installation by reversing the removal procedure.

OIL PUMP

A self-regulating plunger type oil pump is used on all models. The pump is located in drilling in the crankcase and is operated by a push rod from the camshaft. Refer to Fig. L66 for an exploded view of oil pump assembly. Normal oil pressure is 200 kPa (29 psi) at 1500 rpm and minimum oil pressure is 70 kPa (10 psi) at 1000 rpm.

To service oil pump, drain oil and remove sump. Withdraw oil pump assembly and renew if necessary.

AXIAL COOLING FAN

TL2 and TL3 Engines

The axial flow fan is belt driven from the crankshaft pulley. To remove fan, remove fan cowl, belt guard and belt. Remove fan housing mounting cap screws, then remove fan from engine.

To disassemble fan, remove fan pulley (25 – Fig. L67). Press or tap fan shaft (5) out of fan (16) and fan body (14). Remove and inspect bearings and renew if necessary.

When reassembling fan, pack bearings with grease prior to reinstalling. Tighten pulley nut to 92 N·m (68 ft.-lbs.). Make certain there is clearance between fan blades and fan body of 0.25 mm (0.010 inch).

LISTER

Model	No. Cyls.	Bore	Stroke	Displ.
HR2	2	108 mm (4.25 in.)	114 mm (4.5 in.)	2089 cc (127.5 cu. in.)

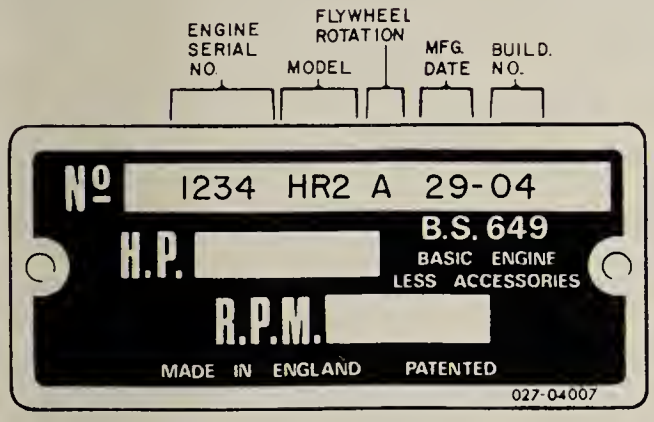


Fig. L70—View of typical engine identification plate used. To ensure use of proper parts and specifications, use complete number.

The HR2 is a four-stroke, air-cooled, direct injection diesel engine with vertical cylinders. Engine type can be identified by the last two digits of engine number found on plate attached to fuel pump; housing door (Fig. L70). Standard crankshaft rotation is counterclockwise as viewed from flywheel end.

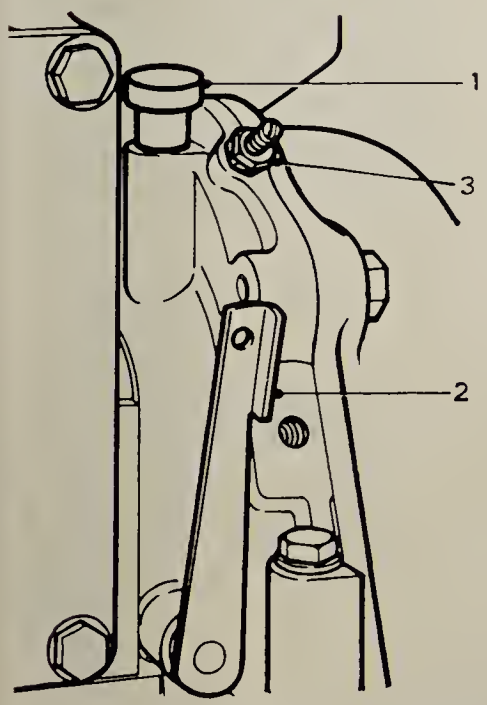


Fig. L71—Basic engine controls used on Model HR engines.

1. Overload trip
2. Control lever
3. Governor adjusting screw

MAINTENANCE

STARTING PROCEDURES

HR engines have a manual crank start as standard equipment. Electric starters may be found on some engines.

Before starting, check fuel and oil levels. If engine is equipped with fuel primer pump, prime fuel filter by using lever on pump. Move compression release levers away from flywheel and crank engine slowly 3-10 times according to temperature and period of "down time" in order to prime oil system and combustion chambers. In cold weather, lift overload stop to allow pumps to deliver extra fuel (Fig. L71). After priming, crank engine until maximum speed is obtained and release compression release levers.

LUBRICATION

Under normal operating conditions, recommended engine oil is heavy-duty diesel lubricating oil that equals or exceeds API service classification CC. If engine is operated under continual heavy load and high ambient temperature, or if sulfur content in fuel exceeds 0.6%, API service classification CD oil is recommended. However, manufacturer does not recommend using CD oil in a new or reconditioned engine until after the first oil change or 250 hours of operation as lubricating properties of CD oil may inhibit running-in if engine is operating under light load conditions. Multigrade oil that meets MIL-L-2104B or MIL-L-2104C specifications may be used but is not approved for use in heavy-duty applications.

If operating temperatures fall below minus 15°C (5°F) SAE 5W oil should be used. From minus 15°C (5°F) to 4°C (40°F), use SAE 10W. For temperatures between 4°C (40°F) and 30°C (85°F), SAE 20W-20 is recommended. Above 30°C (85°F) use SAE 30.

Recommended oil change interval is every 250 hours of operation with filter renewal at the same time. Crankcase capacity is approximately 10.2 liters (10.8 quarts). Check oil level with dipstick; do not overfill.

Refer to Fig. L72 for a schematic view of lubrication system.

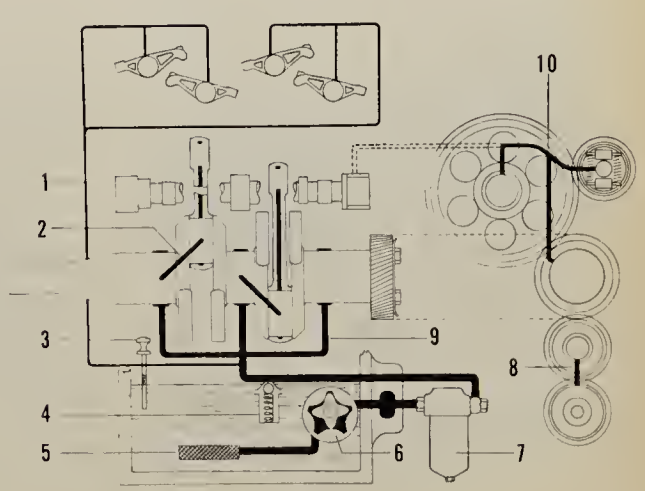


Fig. L72—Diagram of typical lubrication system.

1. Oil pipe to rocker arm
2. Oil passage for rod bearings
3. Dipstick
4. Pressure relief valve
5. Pickup screen
6. Oil pump
7. Oil filter
8. Oil feed to idler gear
9. Oil pipe to main bearings
10. Oil pipe to gear train

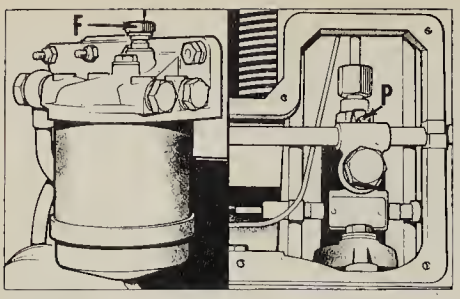


Fig. L73—To bleed air from fuel system, loosen bleed screw (F) on filter base and bleed screws (P) on fuel pumps.

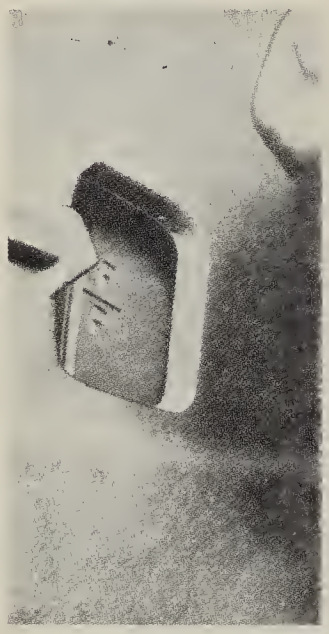


Fig. L74—To check fuel pump timing, set control lever to "RUN" position and align timing marks on flywheel and fan shroud as shown.

INJECTION TIMING. A separate Bryce Berger fuel injection pump is used for each cylinder. Fuel pumps are mounted on side of crankcase and are actuated by lobes on the engine camshaft. Injection timing is adjusted by changing thickness of pump mounting shim gaskets (18–Fig. L78).

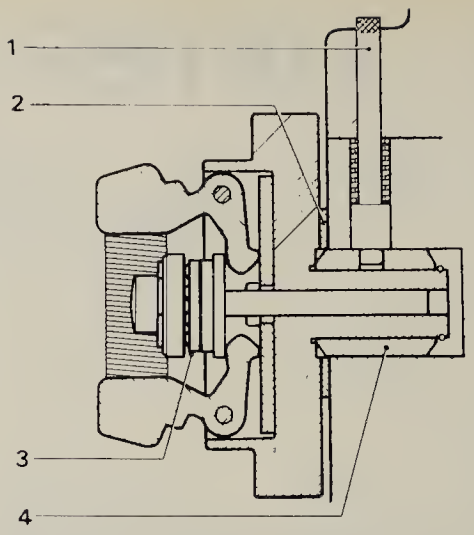


Fig. L76—Governor gear is driven directly by the camshaft and runs in a renewable bearing.

1. Spring-loaded dowel pin
2. Thrust washer
3. Thrust bearing & shaft assy.
4. Governor bearing

To check injection timing, turn the flywheel to firing position for cylinder/pump being checked (Fig. L74). Remove fuel injector pipe from pump. Remove delivery valve holder, delivery valve and spring, then reinstall delivery valve holder. Place control lever in "run" position. Note that fuel should flow from delivery valve holder at this time. Turn flywheel in opposite direction of rotation approximately ¼ turn slowly in normal direction until fuel just stops flowing from the delivery valve. At this point beginning of injection occurs and firing mark, FP on early models or Z on late models, on flywheel should be opposite arrow on fan shroud (Fig. L74) if timing is correct.

If timing marks are not aligned, change thickness of shims between pump body and crankcase as necessary. To advance timing, remove shims; to retard timing, add shims. Changing shim thickness 0.13 mm (0.005 inch) will change timing approximately 1½ crankshaft degrees. When timing is correct, reinstall delivery valve and tighten holder to 54 N·m (40 ft.-lbs.).

Turn flywheel to firing position for second cylinder and repeat timing procedure for the other pump.

FUEL SYSTEM

Number 2 diesel fuel is recommended for most operating conditions. Number 1 diesel fuel may be used for light duty or cold weather operation.

FILTER AND BLEEDING. Manufacturer recommends renewing fuel filter after every 1500 hours of operation or sooner if engine indicates signs of fuel starvation (surging or loss of power). After servicing fuel filter, air must be bled from system.

Whenever fuel filter is changed or fuel line opened, air must be bled from the system. To bleed system, fill fuel tank and remove fuel injection pump door. Loosen bleed screw (F–Fig. L73) on top of fuel filter body; tighten when air-free flow is obtained. Start with fuel injection pump nearest the filter and loosen bleed screws (P) one at a time. Tighten screw when air-free flow is obtained.

CAUTION: Care should be taken to prevent large flow of fuel into crankcase.

GOVERNOR

Two types of gear driven flyweight governors are used and are located in top of gear case. A constant or variable speed (Fig. L75) governor assembly rotates in a renewable bearing (4–Fig. L76) and is driven by the camshaft. The governor lever operates the fuel pumps. Governor weights and springs may be serviced separately. To ensure use of correct parts and adjustments, contact an authorized service department.

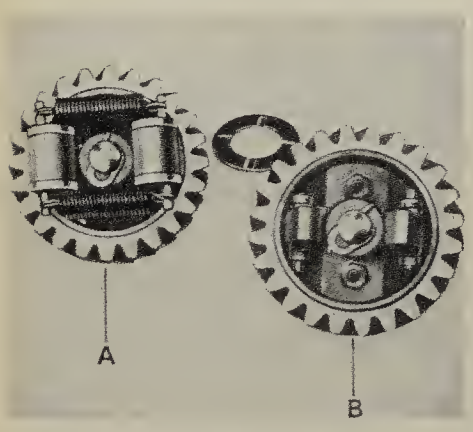


Fig. L75—Two types of gear driven flyweight governors are used. A constant speed "A" or variable speed "B" governor is located at the top of the gear case.

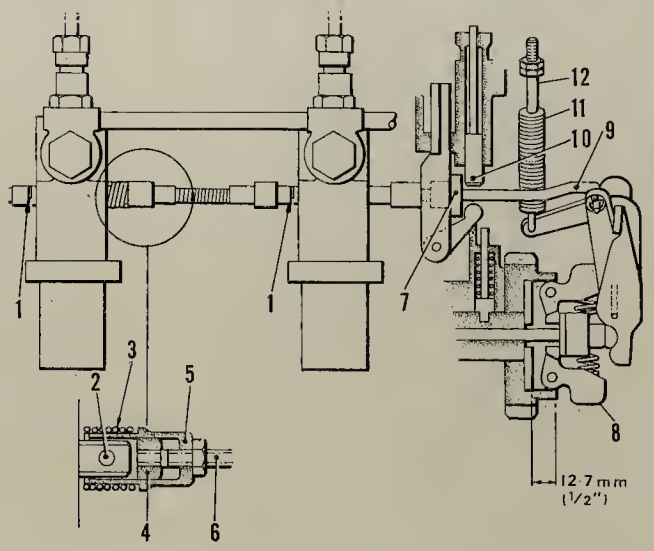


Fig. L77—To set fuel pump and governor, set engine control to "RUN" position. Refer to text for details.

1. Calibration mark
2. Shackle pin
3. Idling spring
4. Shackle
5. Adjusting sleeve
6. Connecting rod
7. Overload stop
8. Governor flyweight assy.
9. Rod
10. Overload trip
11. Speeder spring
12. Adjusting screw

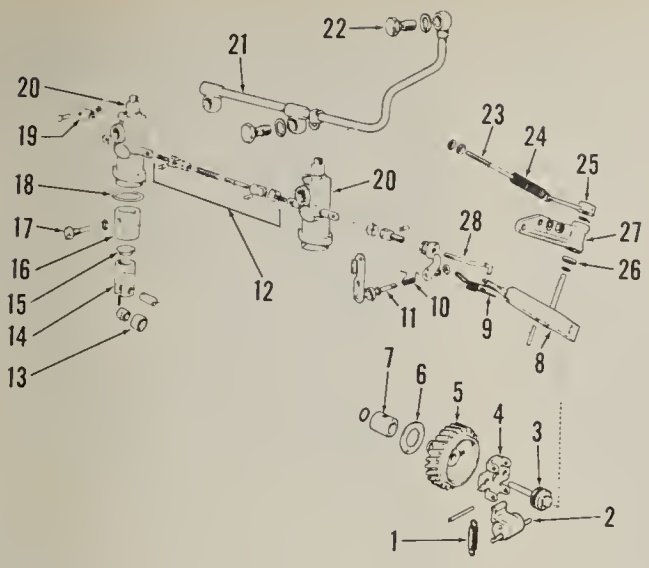


Fig. L78—Exploded view of fuel pump and governor assemblies.

1. Governor weight spring
2. Governor weight
3. Thrust bearing & shaft assy.
4. Weight carrier
5. Governor gear
6. Thrust washer
7. Bearing
8. Governor lever
9. Spring
10. Return spring
11. Stopping lever assy.
12. Rack assy.
13. Roller & bushing
14. Tappet
15. Tappet cap
16. Tappet guide
17. Locating pin
18. Shim
19. Stop sleeve
20. Fuel pump
21. Fuel line
22. Swivel union plug
23. Adjusting screw
24. Speeder spring
25. Governor lever
26. Ball bearing
27. Bracket

To calibrate fuel injection pump linkage and set governor, set engine control to "RUN" position. Adjust fuel injection pump linkage so calibration marks (1–Fig. L77) coincide with sides of pump bodies within 0.13 mm (0.005 inch). Rack must move freely after adjustment. Adjust overload stop (7–Fig. L77) so when it touches overload trip (10), calibration marks are aligned with edge of pump bodies.

To set governor, lift overload trip. Adjust rod (9) (remove cotter pin and screw in or out), with calibration marks aligned, so the distance between governor weight and bottom edge of thrust bearing is 12.7 mm (½ inch).

Engines equipped with variable speed governors use an adjustable idling spring (insert–Fig. L77). The spring rides against fuel injection pump and applies pressure on pump rack to eliminate "hunting" or surging. To adjust idling spring (3), main speeder spring (11) must be completely loosened. Rotate adjusting sleeve (5) until idle speed is about one-third rated engine speed. Main speeder spring should be adjusted so it just begins to increase engine speed.

REPAIRS

TIGHTENING TORQUES

Refer to the following table for special tightening torques. All fasteners are metric.

Connecting rod	92 N·m (68 ft.-lbs.)
Cylinder head	108 N·m (80 ft.-lbs.)
Flywheel	540 N·m (400 ft.-lbs.)
Fuel pump delivery valve holder	54 N·m (40 ft.-lbs.)
Injector cap nut	88 N·m (65 ft.-lbs.)
Injector clamp	20 N·m (15 ft.-lbs.)
Valve rocker cover	20 N·m (15 ft.-lbs.)

VALVE ADJUSTMENT

To adjust valve clearance, first remove cylinder head cover. Turn crankshaft until piston for cylinder being adjusted is at top dead center on compression stroke. Loosen locknut and turn rocker arm adjusting screw (17–Fig. L80) until appropriate size feeler gage can be inserted between rocker arm and valve stem end. Recommended clearance with engine cold is 0.38-0.43 mm (0.015-0.017 inch) for intake and exhaust. Repeat procedure for remaining cylinder. Manufacturer recommends adjusting valve clearance after the first 25 hours, 250 hours and every 500 hours thereafter until clearance remains constant. Then, adjustment interval can be extended to 1500 hours.

To adjust compression release mechanism (9–Fig. L79), proceed as follows: On engines with an oil filler hole in cylinder head covers, compression release is adjusted through these openings. Turn crankshaft until piston is at TDC on compression stroke. Move lever to actuate compression release. Loosen locknut and turn adjusting screw down until it touches the rocker arm, then turn screw an additional ¾ turn and tighten locknut. Repeat procedure for second cylinder.

When cylinder head cover does not have a filler opening, adjust compression release screw (with cover removed) until it just touches rocker arm when cover is reinstalled and release lever is operated. Then, remove cover and turn screw down an additional ¾ turn. Tighten locknut and reinstall cover. Repeat procedure for second cylinder. Tighten cylinder head cover nuts to 20 N·m (15 ft.-lbs.).

CYLINDER HEAD

Two-piece cylinder heads are used. Top half (top plate) is cast iron and contains the valve gear and breather tube. Lower half is aluminum alloy and contains the valve seat inserts. Valve guides are a press fit and hold the cylinder head valves together.

Be sure to identify cylinder heads before removal so they can be reinstalled in their original location. When heads are removed, place shims and gasket from each cylinder with respective cylinder head for use in reassembly. When servicing cylinder head, the two

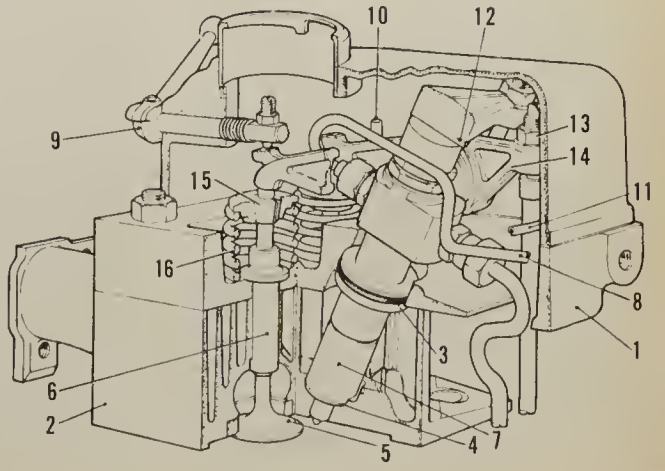


Fig. L79—Cross-sectional view of cylinder head assembly.

1. Top plate
2. Cylinder head
3. Injector seal
4. injector gasket
5. Exhaust valve
6. Valve guide
7. Injector
8. Leak-off pipe
9. Compression release lever
10. Breather tube
11. Oil pipe to rocker arms
12. Injector clamp
13. Rocker arm adjusting screw
14. Rocker arm
15. Valve keepers
16. Valve spring

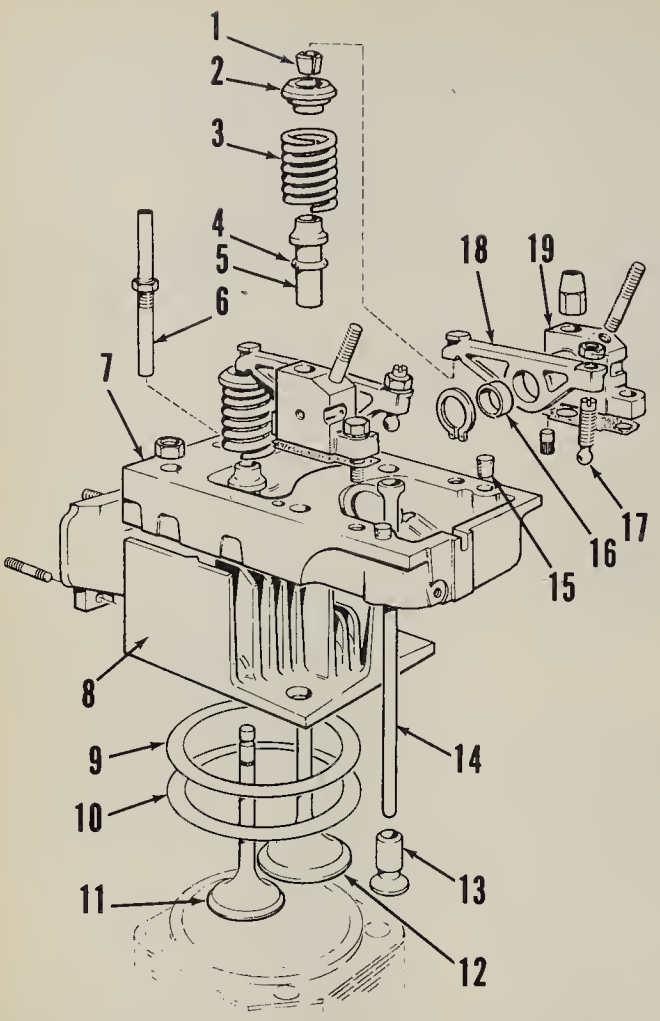


Fig. L80—Exploded view of cylinder head assembly.

1. Valve keeper
2. Retainer
3. Valve spring
4. Seal (intake only)
5. Valve guide
6. Breather tube
7. Top plate
8. Cylinder head
9. Shim
10. Head gasket
11. Exhaust valve
12. Intake valve
13. Cam follower
14. Push rod
15. Rubber plug
16. Bushing
17. Adjusting screw
18. Rocker arm
19. Rocker shaft bracket

rubber plugs (15 – Fig. L80) in top face of head should not be removed.

Clearance between piston and cylinder head is adjusted using shims (9). To check clearance, place two pieces of soft lead wire 1.5 mm (0.062 inch) thick on head. Hold wires in place with a small amount of grease making sure they are clear of valves and in line with piston pin as near as possible. Reinstall head with gasket and tighten stud nuts to 108 N·m (80 ft.-lbs.). Crank piston past TDC twice, then remove cylinder head and measure thickness of wire. Desired clearance is 1.07-1.14 mm (0.042-0.045 inch). To adjust clearance, install shims (9) between cylinder head and the gasket (10).

During final assembly, a high melting point grease should be used to hold shims and head gasket in place. Use grease sparingly and do not apply grease on cylinder side of head gasket. Manufacturer recommends that a thread sealer be used on cylinder head nuts, studs and area of top plate in contact with nuts. Install nuts with grade symbol facing upward. Before tightening cylinder head nuts, install manifold or use a straightedge to ensure alignment or intake and exhaust ports. Then, tighten nuts evenly to 108 N·m (80 ft.-lbs.). Reinstall injectors after cylinder head nuts have been tightened. Complete installation by reversing the removal procedure.

VALVE SYSTEM

The valve guides are a press fit into the cylinder head valves. A rubber seal ring (4 – Fig. L80) is used on the intake guide. The guides are not interchangeable. When renewing guides, apply sealing compound to outside of guide and use suitable installing tool to prevent damage to guide. Valve guide inner diameter should be 91.5-9.53 mm (0.3745-0.3753 inch). Valve stem diameter is 9.44-9.46 mm (0.3718-0.3723 inch). Desired clearance for valves in guides is 0.05-0.09 mm (0.0022-0.0037 inch) with a wear limit of 0.13 mm (0.005 inch).

Desired valve seat width is 2.78-3.20 mm (0.107-0.127 inch) for intake and 2.54-2.89 mm (0.100-0.114 inch) for exhaust. With valves installed, top of intake valve should be 0.96-1.27 mm (0.038-0.050 inch) below combustion surface cylinder head and exhaust valve should be 0.84-1.14 mm (0.033-0.045 inch) below head surface.

Rocker arm bushing bore should be 25.40-25.41 mm (1.000-1.0005 inch) and rocker shaft diameter should be 25.36-25.37 mm (0.9985-0.9988 inch). Desired operating clearance is 0.02-0.05 mm (0.001-0.002 inch) with a wear limit of 0.08 mm (0.003 inch).

Intake and exhaust valve springs are identical. Spring free length should be 56.95-59.13 mm (2.242-2.328 inches). Renew valve springs if distorted, pitted or rusted. Manufacturer recommends renewing valve springs after 6000 hours of operation.

INJECTOR

To remove injector, remove cylinder head cover and disconnect fuel lines. Plug all openings to prevent entry of dirt. Remove injector clamp and withdraw injector with seal ring and washer.

When reinstalling injector, renew copper washer and seal ring. Tighten injector clamp to 20 N·m (15 ft.-lbs.), then tighten injector high pressure line.

WARNING: Fuel leaves the injector nozzle with sufficient force to penetrate the skin. When testing, keep yourself clear of nozzle spray.

To check injector, connect to a hand test pump and operate tester lever a few quick strokes to purge air from injector and to make sure nozzle valve is not stuck. Then, operate tester lever slowly while observing tester gage. Opening pressure should be 17225-18235 kPa (2500-2645 psi). A plug in end of nozzle cap nut can be removed for access to pressure adjusting screw.

The injector nozzle has four spray holes each 0.27 mm (0.010 inch) in diameter. Spray pattern should be symmetrical and well atomized. If spray holes are blocked, injector should be overhauled or renewed.

If injector is disassembled, do not use wire brush, emery cloth or hard metal tools to clean injector. If more than one injector is disassembled at the same time, keep parts from each injector separated as they should not be interchanged. Nozzle spray holes may be cleaned by inserting a cleaning wire slightly smaller in diameter than the orifice hole diameter. Be sure nozzle needle slides freely in nozzle valve body. If needle sticks, reclean or renew nozzle valve assembly.

When reassembling injector, rinse all parts in clean diesel fuel and assemble while wet. Tighten nozzle holder nut to 88 N·m (65 ft.-lbs.). Retest injector as previously outlined.

INJECTION PUMPS

The Bryce Berger fuel injection pumps are located in a housing which is mount-

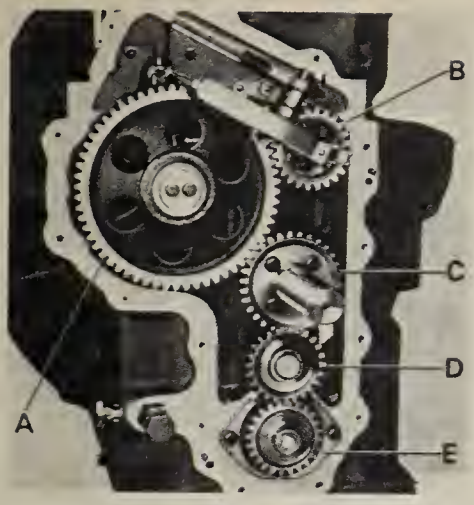


Fig. L81—Basic gear train used on HR engines. Initial backlash between gears is 0.02-0.23 mm (0.001-0.009 inch) with maximum backlash of 0.30 mm (0.0123 inch).

A. Camshaft gear
B. Governor gear
C. Crankshaft gear
D. Idler gear
E. Oil pump gear

ed to top of crankcase. To remove pumps, first shut off fuel supply or drain fuel tank. Remove pump housing cover. Disconnect fuel supply pipes and injector high pressure pipes. Disconnect linkage between pumps. Remove pump retaining clamps and lift out injection pumps. Keep adjusting shims with pumps as they are removed for use in reassembly.

It is recommended that fuel pumps be tested and serviced only by a shop qualified in diesel fuel injection repair.

To reinstall pump, reverse the removal procedure using original mounting shims. Be sure pump control racks move freely. Check pump timing as outlined in INJECTION TIMING paragraph. Adjust governor linkage as outlined in GOVERNOR section.

PISTON, PIN, RINGS AND CYLINDER

The piston is equipped with a barrel faced, chrome, keystone type top ring; two tapered face, rectangular center compression rings; a spring expander type oil control ring above the piston pin and a slotted oil scraper ring below the piston pin. The full floating piston pin is retained in piston by two snap rings.

NOTE: Mark cylinder number on piston, connecting rod and cylinder barrel prior to removal. All components should be reinstalled in their original location if not renewed.

To disassemble, remove oil sump and cylinder heads. Remove cooling air shrouds. Remove crankcase side cover with fuel transfer pump (if so equipped) and lubricating oil pipes. Remove connecting rod caps. Withdraw cylinder, piston and connecting rod as an assembly. Retain all shims and gaskets with their respective cylinder for use in reassembly.

Thoroughly clean piston and cylinder, then check for scoring, wear and other damage. Piston diameter at bottom of skirt should be 107.76-107.78 mm (4.2425-4.2435 inches) and the cylinder bore should be 108.03-108.05 mm (4.253-4.254 inches).

Piston top ring groove is a keystone type and a special gage is required to check groove wear. The groove width for center compression rings is 3.28-3.30 mm (0.129-0.130 inch). Recommended side clearance between compression rings is 3.28-3.30 mm (0.129-0.130 inch). Recommended side clearance between compression rings and piston grooves is 0.10-0.15 mm (0004-0.006 inch) with a wear limit of 0.20 mm (0.008 inch). Piston groove width for both oil scraper rings is 4.81-4.84 mm (0.1895-0.1905 inch). Side clearance for both oil scraper rings should be 0.05-0.10 mm (0.002-0.004 inch) with a wear limit of 0.15 mm (0.006 inch).

With ring positioned squarely in cylinder bore, measure ring end gap with a feeler gage. Refer to following table for recommended end gap dimensions.

Ring Gap	Desired
Top	0.66-0.91 mm (0.026-0.036 in.)
Maximum	1.14 mm (0.045 in.)
Compression	0.48-0.66 mm (0.019-0.026 in.)
Maximum	0.96 mm (0.038 in.)
Top scraper	0.66-0.91 mm (0.026-0.036 in.)
Maximum	1.22 mm (0.048 in.)
Bottom scraper	0.53-0.71 mm (0.21-0.028 in.)
Maximum	0.96 mm (0.038 in.)

Piston pin diameter is 39.684-39.689 mm (1.56235-1.56255 inch). Desired operating clearance in connecting rod bushing is 0.021-0.047 mm (0.0009-0.0018 inch) while maximum allowable clearance is 0.076 mm (0.003 inch).

When reassembling, be sure piston is installed on connecting rod with the wording "CAMSHAFT SIDE" on top of piston on the same side as "double" cylinder numbers stamped on connecting rod. One side of center compression rings is marked "TOP" and must be installed accordingly. Lubricate piston and cylinder bore with clean oil, then install piston into cylinder. Assemble piston and cylinder assembly onto crankcase making certain V-notch on top fin of cylinder barrel is towards flywheel end of engine and "CAMSHAFT SIDE" marking on piston and "double" cylinder numbers on connecting rod are all facing camshaft side of engine. Tighten connecting rod cap nuts to 92 N·m (68 ft.-lbs.).

CONNECTING ROD

A forged steel connecting rod is used with a precision, insert type bearing in the big end and a bushing in the small end.

Standard crankpin diameter is 69.82-69.83 mm (2.7488-2.7492 inches). Recommended rod bearing clearance is 0.05-0.09 mm (0.0020-0.0035 inch) and maximum allowable clearance is 0.14 mm (0.0055 inch).

Piston pin diameter is 39.684-39.689 mm (1.5624-1.5625 inches) and small end bushing inner diameter should be 39.71-39.73 mm (1.5634-1.5642 inches). Recommended operating clearance is 0.021-0.047 mm (0.0009-0.0018 inch) with a wear limit of 0.076 mm (0.003 inch).

Connecting rod and cap are marked with double cylinder numbers (11 and 22). Make certain these numbers are on the same side and face camshaft side of engine. Tighten connecting rod cap nuts to 90 N·m (68 ft.-lbs.).

TIMING GEARS AND END COVER

Various styles of end covers are used depending on engine application. The oil seal for the crankshaft extension is located in the end cover. Be sure to lubricate the lip of a new oil seal and protect seal when reinstalling cover.

The governor assembly and drive gear (B – Fig. L81) can be removed as a unit by first removing governor lever, then lift the spring loaded dowel pin (1 – Fig. L76) above the bearing and withdraw complete assembly from crankcase. When reinstalling, make sure large hole in bearing (4) is towards the top and thrust washer (2) is positioned between the drive gear and crankcase.

The camshaft gear (A – Fig. L81) is retained by two screw cap screws, a locating plate and Woodruff key. The crankshaft gear (C) is retained by four cap screws and located on crankshaft by

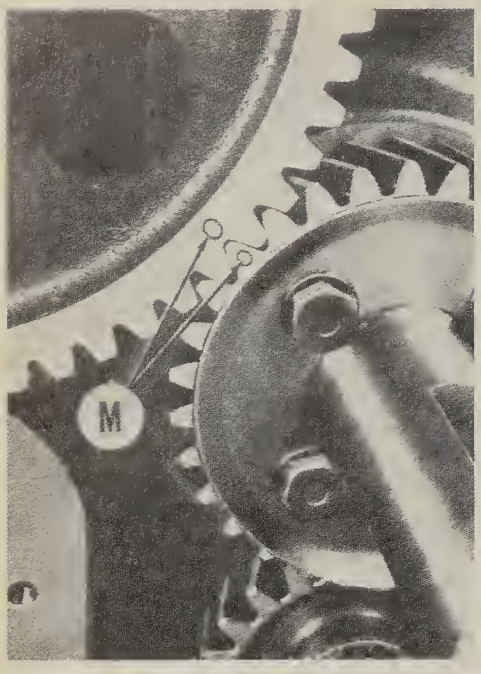


Fig. L82—Align timing marks (M) as shown when reinstalling timing gears.

two dowels. Be sure to align timing marks (M – Fig. L82) when reinstalling.

The oil pump idler gear (D – Fig. L81) is retained by a snap ring and thrust washer. The idler stub shaft is a press fit in crankcase and is also retained by a split pin inside the crankcase. The oil pump and gear (E) may be removed as an assembly after removing two mounting cap screws. Oil pump gear is retained by a split pin on oil pump shaft.

CAMSHAFT

To remove camshaft, remove cylinder heads, fuel pump housing cover, crankcase side cover and gearcase end cover. Release speeder spring, disconnect and remove governor link assembly. Disconnect fuel lines and remove fuel pumps and injectors. Remove fuel pump tappet guide locating pins and lift out tappet assemblies (Fig. L83). Remove oil supply pipe plug from camshaft locating bushing. Lift cam followers and carefully withdraw camshaft assembly and locating bushing.

The camshaft is carried in bronze bushings at the flywheel end and in crankcase dividers. A cast iron bushing (22 – Fig. L84) is used at the gear end and is secured by oil supply line plug. All bushings, except locator bushing, are a press fit. Bronze bushing bores should be 44.40-44.42 mm (1.7483-1.7487 inches). Diameter of camshaft journals is 44.34-44.35 mm (1.7455-1.7460 inches). Desired operating clearance is 0.06-0.08 mm (0.0023-0.0032 inch) with a wear limit of 0.13 mm (0.005 inch). Inside diameter of locating bushing should be 34.92-34.95 mm (1.3750-1.3762 inches)

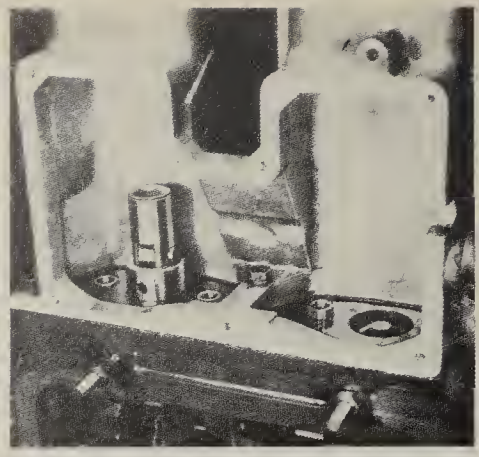


Fig. L83—To service camshaft, remove fuel pumps, fuel pump tappets, tappet guide locating pins and guides.

and camshaft journal diameter is 34.86-34.87 mm (1.3725-1.3730 inches). Desired operating clearance is 0.05-0.09 mm (0.002-0.0037 inch) while maximum allowable clearance is 0.13 mm (0.005 inch).

When renewing bushings, soak bronze bushings in engine oil for four hours before installing. Install bushings with thinnest part of bearing wall (marked with a dot) towards the top. Install cast iron locating bushing with locating hole to the top. Camshaft end play should be 0.38 mm (0.015 inch).

Timing marks on camshaft and crankshaft gears should be aligned as shown in Fig. L82. Fuel pump timing should be checked as described in FUEL SYSTEM section.

CRANKSHAFT AND BEARINGS

The crankshaft is supported in split bushings at both ends of shaft. A center bearing is mounted in a split bearing carrier (1 and 2 – Fig. L84) and is located in crankcase by hollow dowel pin.

To remove crankshaft, drain oil and remove oil sump. Remove cylinder heads, pistons and cylinders, timing gear cover (21 – Fig. L85), crankshaft extension (22) and crankshaft gear, flywheel and fan shroud (10). Disconnect and remove main bearing lubricating oil pipes. Remove bearing housing (3) with shims and thrust washer. Thread a cap screw into the end of center bearing carrier locating dowel and withdraw dowel. Remove crankshaft assembly from crankcase.

Inspect crankshaft and bearings for excessive wear or other damage. If a bearing failure has occurred, be sure drilled oil passages in crankshaft are clean before reassembling.

Crankshaft main journal diameter when new is 82.54-82.55 mm (3.2496-3.250 inches). Main bearing bore should be 82.59-82.63 mm (3.2516-3.2531 inches). Recommended main bearing clearance is 0.04-0.09 mm (0.0016-0.0032 inch) and maximum allowable clearance is 0.15 mm (0.006 inch).

Crankpin diameter when new is 69.82-69.83 mm (2.7488-2.7492 inches). Recommended rod bearing clearance is 0.05-0.09 mm (0.0020-0.0035 inch) with a wear limit of 0.14 mm (0.0055 inch).

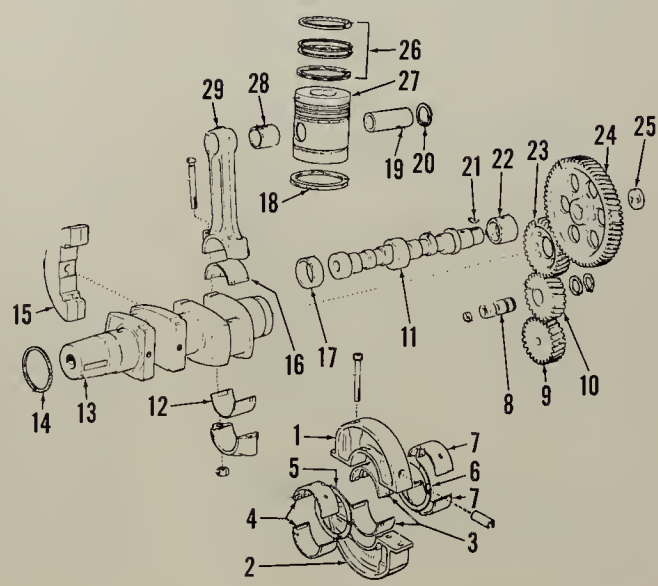
Crankshaft end thrust is taken by copper-faced split thrust washers. Thickness of new thrust washer is 3.10-3.17 mm (0.122-0.125 inch).

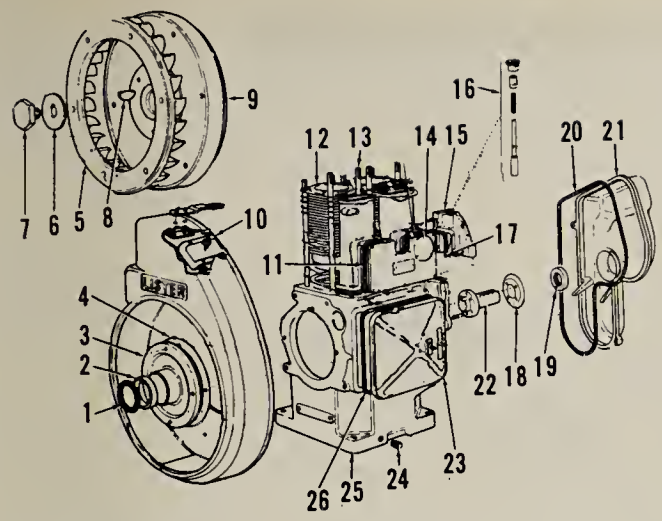
When renewing main bearings, make certain bearing shell with groove is to the top and oil holes are aligned.

To reassemble, proceed as follows: Be sure copper face of split thrust washer is towards crankshaft and tab is towards

Fig. L84—Exploded view of crankshaft and camshaft assemblies.

1. Upper center main bearing housing
2. Lower center main bearing housing
3. Center main bearing
4. Main bearing
5. Split thrust washer
6. Thrust washer
7. Main bearing
8. Idler gear shaft & plug
9. Oil pump gear
10. Idler gear
11. Camshaft
12. Rod bearing
13. Crankshaft
14. Oil slinger
15. Balance weight
16. Rod bearing
17. Camshaft bushing
18. Piston ring
19. Piston pin
20. Retaining ring
21. Key
22. Camshaft bearing
23. Crankshaft gear
24. Camshaft gear
25. Locating plate
26. Piston rings
27. Piston
28. Rod bushing
29. Connecting rod





1. Felt washer
2. Oil retaining ring
3. Main bearing housing
4. Bearing housing gasket
5. Fan
6. Lockwasher

Fig. 85—Exploded view of basic crankcase assembly.

7. Flywheel retaining screw
8. Key
9. Flywheel
10. Fan shroud
11. Gasket
12. Cylinder barrel
13. Stud
14. Fuel pump housing
15. End plate
16. Overload trip assy.
17. End plate gasket
18. Oil slinger
19. Oil seal
20. Gear cover gasket
21. Gear cover
22. Crankshaft extension
23. Crankcase side cover
24. Drain plug
25. Crankcase assy.
26. Gasket

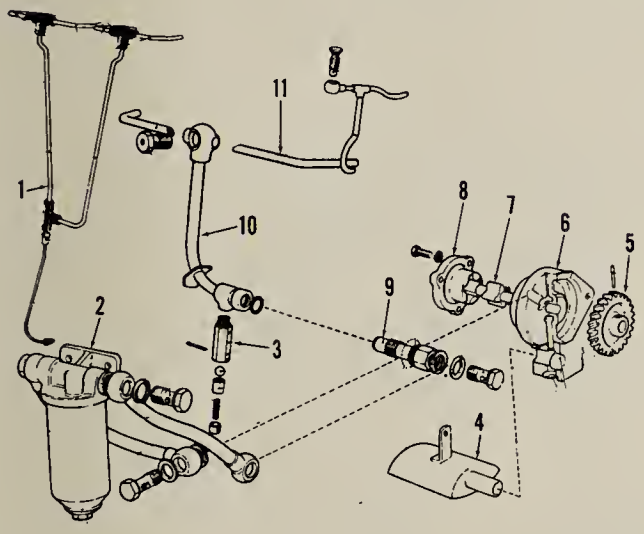


Fig. L86—Exploded view of lubrication system used.

1. Oil pipe between cylinders
2. Oil filter & mounting bracket
3. Oil pressure relief valve assy.
4. Pick-up screen
5. Drive gear
6. Pump housing
7. Spindle & impeller
8. Eccentric ring
9. Connector
10. Main oil supply pipe
11. Oil pipe to main bearing, camshaft & governor

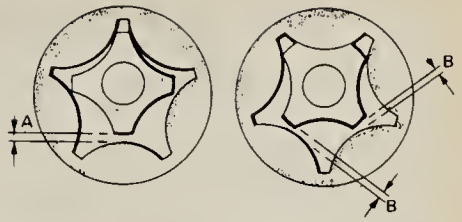


Fig. L87—The gerotor type pump wear limits are as follows: A—0.20 mm (0.008 inch); B—0.18 mm (0.007 inch); End clearance—0.15 mm (0.006 inch).

the top. Align locating hole in center bearing carrier with hole in side of crankcase and install dowel. Install main bearing housing, then check crankshaft end play. Recommended end play is 0.13-0.25 mm (0.005-0.010 inch) and is adjusted using shims (4 – Fig. L85) as required between bearing housing and crankcase. Apply sealing compound to shims during final assembly. Align timing marks (M – Fig. L82) on crankshaft gear and camshaft gear. Tighten flywheel mounting screw to 542 N·m (400 ft.-lbs.). Complete installation by reversing the removal procedure.

OIL PUMP

The gerotor type oil pump is driven by an idler gear from the crankshaft gear. Normal oil pressure is 205-315 kPa (30-45 psi). A pressure relief valve (3 – Fig. L86) is located in the oil gallery pipe.

To remove oil pump, drain the oil and remove the timing gear cover. Unbolt and remove pump assembly. Renew oil pump if clearances indicated in Fig. L87 exceed the following values.

Point A.....0.20 mm (0.008 in.)
Point B.....0.18 mm (0.007 in.)
End clearance.....0.15 mm (0.006 in.)

SERVICING LISTER ACCESSORIES

FUEL SYSTEM

LIFT PUMP. A fuel lift pump, when required, is fitted on the crankcase door and operated by a push rod (14–Fig. L90) or (B–Fig. L91) riding against the camshaft. Inlet side of pump is connected to main fuel supply and outlet feeds fuel filter. Complete pump repair kits are available. After completing service, check push rod clearance.

To check clearance, insert push rod and turn engine over until the rod is at its maximum outward travel. On ST and TS engines, install pump gasket and measure clearance. Pump clearance (D–Fig. L91) is 1/32 to 3/64 inch (0.8-1.2 mm). Add pump gaskets as necessary to obtain correct clearance.

On HR engines, with push rod at its maximum outward travel, measure

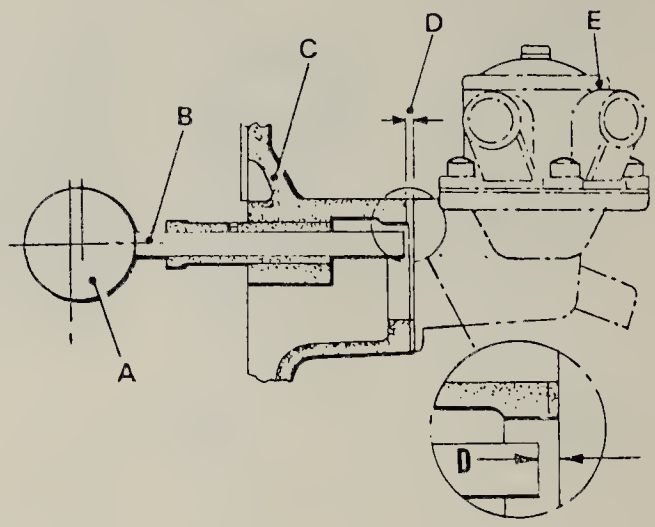


Fig. L91—Cross-sectional view of lift pump used on ST engines. Push rod clearance (D) is 1/32 to 3/64 inch (0.8-1.2 mm).

A. Camshaft
B. Push rod
C. Crankcase door
D. Gasket
E. Lift pump

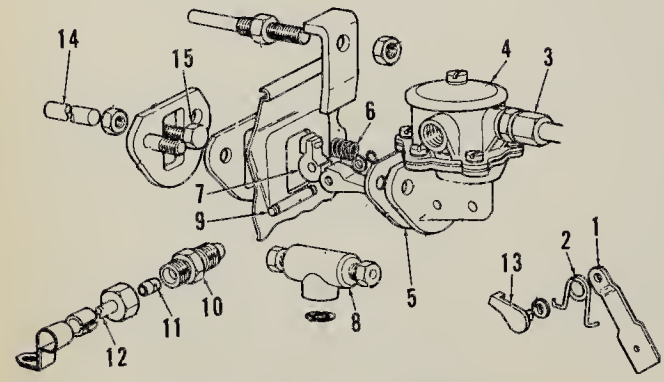


Fig. L90—Exploded view of fuel lift pump.

1. Primer arm
2. Return spring
3. 5/16-inch union fitting
4. Lift pump
5. Gasket
6. Spring
7. Arm
8. "T" fitting & gasket
9. Pin
10. Union
11. Ferrel
12. Union nut
13. Lever
14. Push rod
15. Push rod adjusting screw

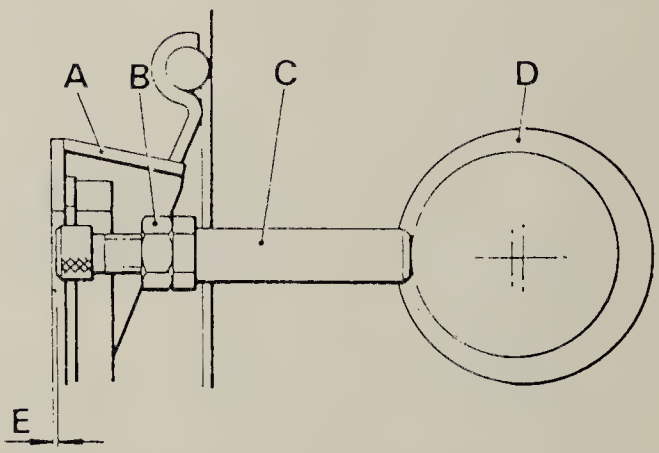
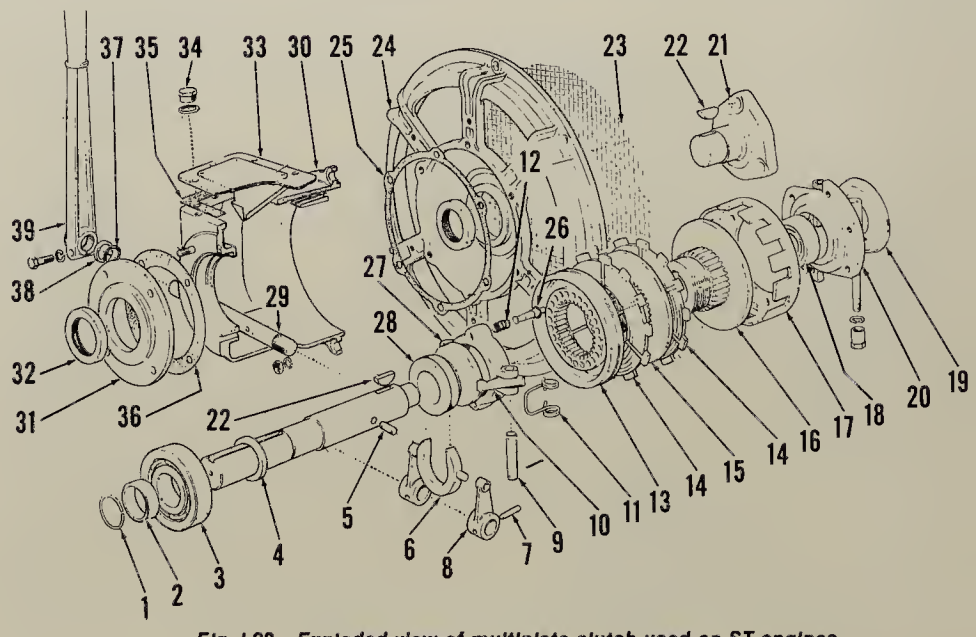


Fig. L92—View of lift pump adjuster used on HR engines. Push rod clearance (E) is 0.018-0.020 inch (0.46-0.50 mm).

A. Crankcase door
B. Locknut
C. Push rod
D. Camshaft



1. Retaining ring
2. Oil seal bushing
3. Ball bearing
4. Clutch shaft assy.
5. Locating pin
6. Sliding yoke
7. Pin
8. Operating lever
9. Pin
10. Clutch engaging arms
11. Spring
12. Locating pin spring
13. Pressure plate
14. Clutch plates
15. Driven disc
16. Clutch hub
17. Clutch body
18. Bearing
19. Oil slinger
20. Clutch drive member
21. Crankshaft extension
22. Key
23. Guard
24. Adapter
25. Gasket
26. Plunger
27. Adjusting ring
28. Engaging cone
29. Operating shaft
30. Clutch housing
31. End cover
32. Oil seal
33. Inspection cover
34. Plug
35. Gasket
36. End cover gasket
37. Seal
38. Seal retainer
39. Operating lever

Fig. L93—Exploded view of multiplate clutch used on ST engines.

distance from push rod to face of crankcase door (E – Fig. L92). Distance should be 0.018-0.020 inch (0.46-0.5 mm). To adjust, remove rod and lengthen or shorten adjuster as required. Reinstall push rod and pump.

CLUTCH. Some ST models are equipped with a multiplate set type clutch (Fig. L93). The lever operated clutch is self-locking. The oil capacity is approximately 5/8 pint of SAE 10 weight oil.

Some HR models are equipped with a single plate clutch for direct drive (Fig. L94) or with a reduction gear (Fig. L95).

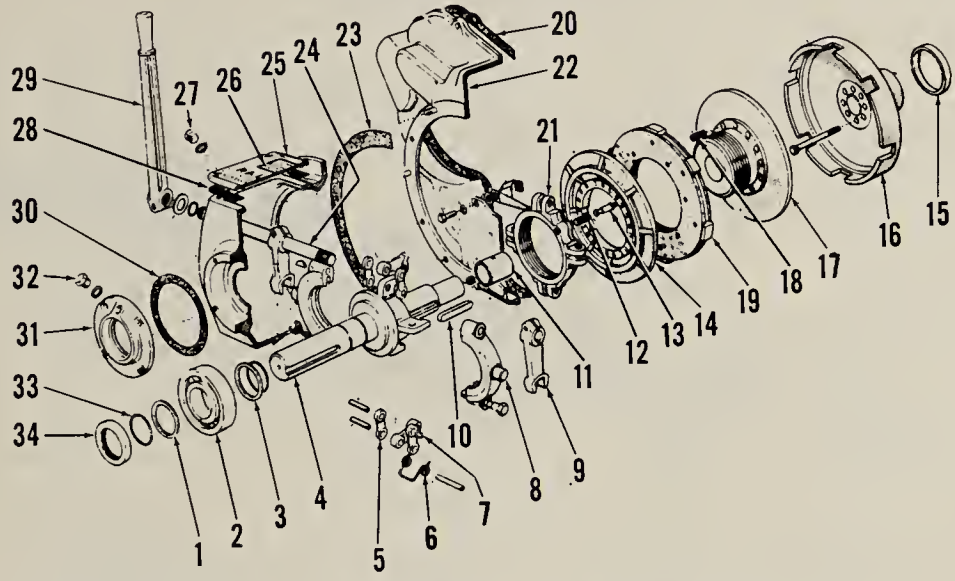


Fig. L94 – Exploded view of direct drive clutch used on HR engines.

1. Retaining washer
2. Ball bearing
3. Retaining ring & washer
4. Clutch shaft assy.
5. Link
6. Spring
7. Toggle lever & link
8. Yoke
9. Operating lever
10. Key
11. Bearing
12. Spring
13. Plunger
14. Pressure plate
15. Spigot ring
16. Clutch drive member
17. Clutch hub
18. Spring
19. Clutch plate
20. Gasket
21. Adjusting ring
22. Adapter
23. Gasket
24. Operating shaft assy.
25. Clutch housing
26. Inspection cover
27. Plug
28. Gasket
29. Operating lever
30. Gasket
31. End cover
32. Oil plug
33. Retaining ring
34. Oil seal

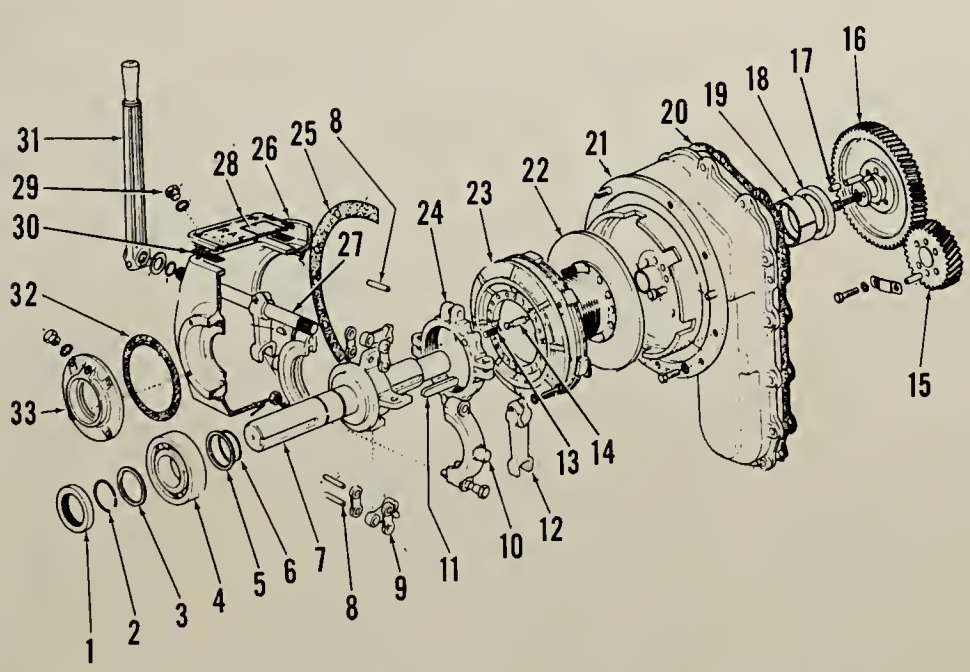


Fig. L95—Exploded view of direct drive clutch with 2:1 reduction gear used on HR engines.

1. Oil seal
2. Retaining ring
3. Washer
4. Ball bearing
5. Washer
6. Retaining ring
7. Clutch shaft assy.
8. Fulcrum
9. Toggle lever & link
10. Operating yoke
11. Key
12. Operating lever
13. Spring
14. Plunger
15. Crankshaft gear assy.
16. Camshaft gear
17. Dowel
18. Spigot ring
19. Split bearing
20. Gasket
21. Adapter
22. Clutch hub
23. Clutch plate assy.
24. Adjusting ring
25. Gasket
26. Clutch housing
27. Operating shaft
28. Inspection cover
29. Plug
30. Gasket
31. Operating lever
32. Gasket
33. End cover assy.

Clutch lubrication is supplied by engine lubrication through a restrictor plug fitted in the end of crankshaft.

To adjust clutch, stop engine and remove inspection cover. Pull plunger (26–Fig. L93 or 13–Fig. L94) and rotate adjusting ring (27–Fig. L93 or 21–Fig. L94) clockwise one to three holes. Check "feel" of clutch lever. Do not adjust tighter than is necessary to transmit full power without slip. Clutch output shaft must turn freely in "neutral" position.

REDUCTION GEAR. A 2:1 or 3:1 reduction gear may be attached to flywheel end on Models ST2 and ST3 (Fig. L96). The gear assembly is secured to fan shroud and a splined drive engages with a shaft extension bolted to the flywheel. A multipurpose gear lubricant is used in gearbox.

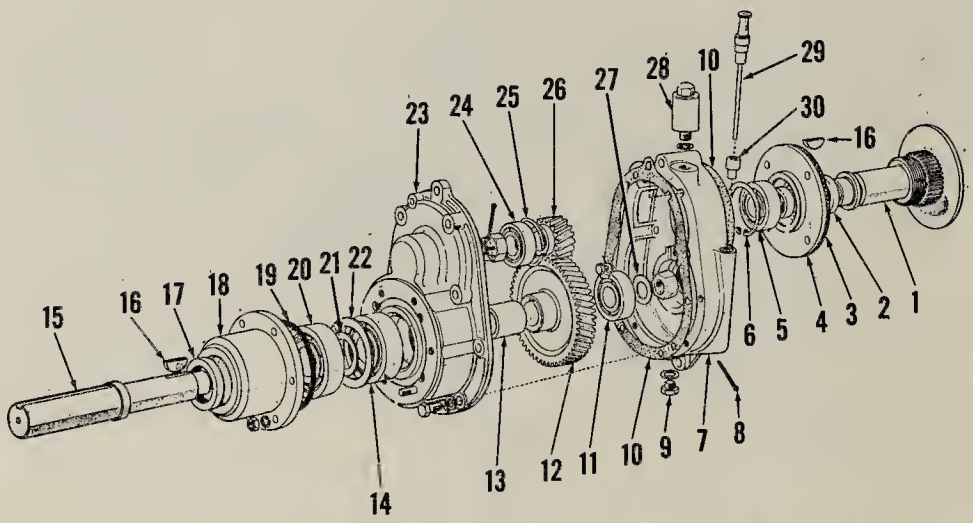


Fig. L96–Exploded view of 2:1 or 3:1 reduction gear used on some ST engines.

1. Clutch shaft assy.
2. Oil seal
3. Gasket
4. Adapter
5. Bearing
6. Snap ring
7. Gear case
8. Cotter pin
9. Drain plug
10. Gasket
11. Bearing
12. Gear (2:1 or 3:1)
13. Spacer
14. Bearing
15. Secondary shaft
16. Key
17. Oil seal
18. Bearing housing
19. Oil ring
20. Bearing
21. Inner spacing washer
22. Outer spacing washer
23. Gear case end cover
24. Roller bearing
25. Retaining ring
26. Pinion (2:1 or 3:1)
27. Packing shim
28. Oil breather
29. Dipstick
30. Adapter

LOMBARDINI

BRIGGS & STRATTON
LOMBARDINI DIESEL, INC.
3402 Oakcliff Road B2
Doraville, Georgia 30340

Model	No. Cyls.	Bore	Stroke	Displ.
3LD450, LDA450	1	85 mm (3.35 in.)	80 mm (3.15 in.)	454 cc (27.7 cu. in.)
3LD510, LDA510	1	85 mm (3.35 in.)	90 mm (3.54 in.)	501 cc (30.6 cu. in.)
3LD510/L, L8	1	85 mm (3.35 in.)	90 mm (3.54 in.)	510 cc (30.6 cu. in.)
4LD640, LDA96	1	95 mm (3.74 in.)	90 mm (3.54 in.)	638 cc (38.9 cu. in.)
4LD640/L, L10	1	95 mm (3.74 in.)	90 mm (3.54 in.)	638 cc (38.9 cu. in.)
FLD705, LDA100	1	100 mm (3.94 in.)	90 mm (3.54 in.)	707 cc (43.1 cu. in.)
4LD820, LDA820	1	102 mm (4.01 in.)	100 mm (3.94 in.)	817 cc (49.8 cu. in.)
4LD820/L, L14	1	102 mm (4.01 in.)	100 mm (3.94 in.)	817 cc (49.8 cu. in.)

All models are four-stroke, single-cylinder, air-cooled diesel engines. Crankshaft rotation is counterclockwise at pto end.

Metric fasteners are used throughout engine.

MAINTENANCE

LUBRICATION

Recommended engine oil is SAE 10W for temperatures below 0° (32°F), SAE 20W for temperatures between 0°C (32°F) and 20°C (68°F) and SAE 40 for temperatures above 20°C (68°F). API classification for oil should be CD. Oil sump capacity is 1.75 liters (1.85 quarts) on Models 3LD450, LDA450, 3LD510, LDA510, 3LD510/L and L8 or 2.6 liters (2.75 quarts) on all other models. Manufacturer recommends changing oil after every 300 hours of operation.

A renewable oil filter is mounted on side of engine crankcase. Manufacturer recommends renewing filter after every 300 hours of operation.

All models are equipped with a pressurized oil system. Minimum allowable oil pressure is 100 kPa (15 psi).

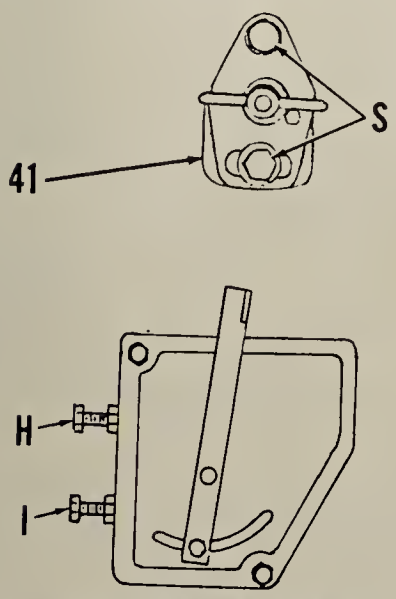


Fig. L1-1—Engine speed adjustment points. Refer to text for adjustment procedure.

ENGINE SPEED ADJUSTMENT

Low idle speed is adjusted by turning idle speed screw (I–Fig. L1-1). Idle speed should be 1000-1100 rpm on all models. Maximum governed speed is adjusted by turning high speed screw (H). Set high idle (no-load) speed 180 rpm above specified governed full-load speed to compensate for governor droop. Normally, full-load speed should be 2200 rpm for Models 3LD510/L, L8, 4LD640/L, L10, 4LD820/L and L14; 2600 rpm for Models 4LD705, LDA100, 4LD820 and LDA820; 3000 rpm for Models 3LD450, LDA450, 3LD510, LDA510, 4LD640 and LDA96. Speeds may vary depending upon application.

Maximum fuel delivery is adjusted by loosening screws (S) and moving adjusting plate (41). Set plate so satisfactory engine acceleration and power are obtained without excessive smoke. Moving plate to the left increases fuel delivery.

FUEL SYSTEM

FUEL FILTER. The fuel filter is located in bottom of fuel tank as shown in Fig. L1-2. Manufacturer recommends renewing fuel filter after every 300 hours of operation. However, fuel filter renewal interval is more dependent upon fuel quality and cleanliness than length of service or operating condi-

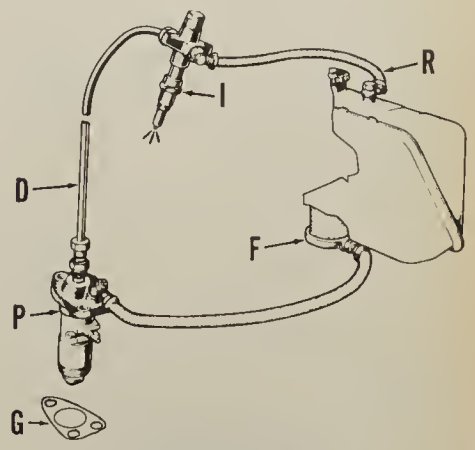


Fig. L1-2—Diagram of fuel system. Some models are also equipped with a fuel transfer pump (not shown), located between fuel tank and injection pump, which ensures constant fuel delivery to injection pump.

D. High pressure delivery line
F. Fuel filter
G. Shim gasket
I. Injector
P. Injection pump
R. Return line

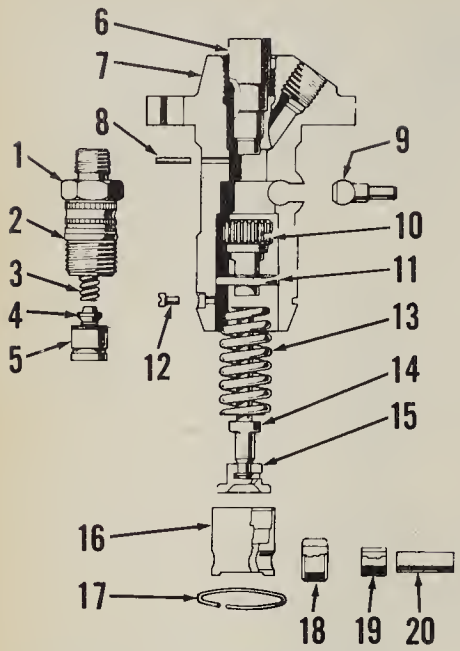


Fig. L1-3—View of fuel injection pump.

1. Delivery valve holder
2. "O" ring
3. Spring
4. Delivery valve
5. Delivery valve seat
6. Barrel
7. Pump body
8. Pin
9. Control rack
10. Pinion
11. Spring seat
12. Pin
13. Spring
14. Plunger
15. Spring retainer
16. Tappet
17. Snap ring
18. Outer roller
19. Inner roller
20. Pin

tions. If engine indicates signs of fuel starvation (loss of power or surging), renew filter regardless of hours of operation. After renewing filter, air must be bled from system as outlined in following paragraph.

BLEED FUEL SYSTEM. To bleed air from fuel system, loosen bleed screw or fuel supply line fitting on injection pump. On gravity feed system, allow fuel to flow from fitting until free of air. On models equipped with fuel transfer pump, manually operate hand primer lever to purge air from fuel supply line. Retighten or bleed screw.

NOTE: If cam which drives transfer pump is at full lift, priming lever cannot be operated. Turn crankshaft one revolution to reposition camshaft.

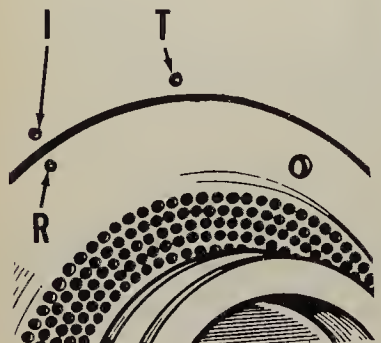


Fig. L1-4—View of timing marks located on air shroud. Refer to text for injection timing.

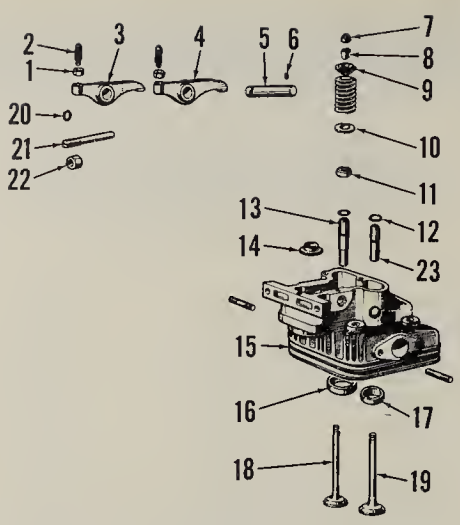


Fig. L1-5—Exploded view of cylinder head assembly.

1. Locknut
2. Adjuster
3. Intake rocker arm
4. Exhaust rocker arm
5. Rocker arm shaft
6. Set screw
7. Cap
8. Keys
9. Spring retainer
10. Washer
11. Oil seal
12. Snap ring
13. Intake valve guide
14. Spring seat
15. Cylinder head
16. Intake valve seat
17. Exhaust valve seat
18. Intake valve
19. Exhaust valve
20. "O" ring
21. Rocker shaft locating pin
22. Lock nut
23. Exhaust valve guide

If engine fails to start, loosen high pressure fuel line at injector. Rotate engine crankshaft until fuel is discharged from injector line. Retighten injection line fitting and start engine.

INJECTION PUMP TIMING

Injection pump timing is adjusted using shim gaskets (G – Fig. L1-2) between pump body and mounting surface on crankcase. To check injection pump timing, unscrew high pressure delivery line (D) fitting from delivery valve holder (1 – Fig. L1-3). Unscrew delivery valve holder and remove spring (3) and delivery valve (4), then screw delivery valve holder (1) into pump body. Move throttle control to full speed position. Rotate crankshaft in normal direction (counterclockwise at pto) so piston is on compression stroke. Note fuel in delivery valve holder will spill out. Stop crankshaft rotation at moment fuel ceases to flow out. At this point, beginning of injection occurs and timing dot (R – Fig. L1-4) on fan plate should be aligned with timing dot (I) on fan shroud. Injection timing should be 24°-26° BTDC on Models 3LD450, LDA 450, 3LD510, LDA510, 3LD510/L, 4LD640 and LDA96. On all other models, injection timing should be 22°-24° BTDC.

Reduce pump mounting shim gasket thickness to advance timing or increase gasket thickness to retard timing. Reinstall delivery valve and spring and tighten holder to a torque of 35 N·m (26 ft.-lbs.). Tighten injection pump retaining screws to 25 N·m (18 ft.-lbs.).

REPAIRS

TIGHTENING TORQUES

Refer to the following table for tightening torques.

Connecting rod:
3LD450, LDA450, 3LD510, LDA510, 3LD510/L, L8 ..... 30 N·m (22 ft.-lbs.)
All other models ..... 45 N·m (33 ft.-lbs.)

Cylinder head:
3LD450, LDA450, 3LD510, LDA510, 3LD510/L, L8 ..... 50 N·m (37 ft.-lbs.)
All other models ..... 78 N·m (58 ft.-lbs.)

Flywheel:
3LD450, LDA450, 3LD510, LDA510, 3LD510/L, L8 ..... 170 N·m (125 ft.-lbs.)
All other models ..... 345 N·m (255 ft.-lbs.)

Injection pump ..... 25 N·m (18 ft.-lbs.)

Injector ..... 25 N·m (18 ft.-lbs.)

Main bearing support:
Flywheel side –
3LD450, LDA450, 3LD510, LDA510, 3LD510/L, L8 ... 30 N·m (22 ft.-lbs.)
All other models ..... 35 N·m (26 ft.-lbs.)
Gear train side –
3LD450, LDA450, 3LD510, LDA510, 3LD510/L, L8 ... 25 N·m (18 ft.-lbs.)
All other models ..... 40 N·m (30 ft.-lbs.)

Oil pan ..... 25 N·m (18 ft.-lbs.)

Oil pump ..... 40 N·m (30 ft.-lbs.)

Oil pump gear ..... 20 N·m (15 ft.-lbs.)

Rocker arm cover ..... 20 N·m (15 ft.-lbs.)

Timing gear cover:
3LD450, LDA450, 3LD510, LDA510, 3LD510/L, L8 ..... 25 N·m (18 ft.-lbs.)
All other models ..... 40 N·m (30 ft.-lbs.)

VALVE CLEARANCE ADJUSTMENT

Valve clearance should be 0.20 mm (0.008 inch) for intake and exhaust valve with engine cold. To adjust clearance, remove rocker arm cover and rotate crankshaft until piston is at TDC on compression stroke. Loosen rocker arm

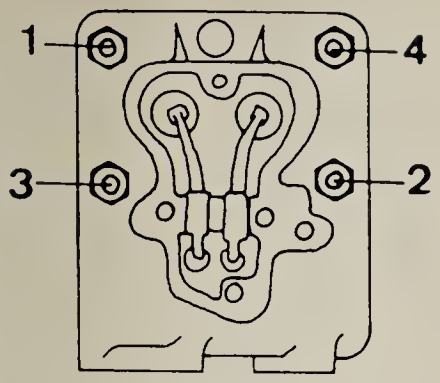


Fig. L1-6—Tighten cylinder head stud nuts in sequence shown.

adjusting screw jam nut, then turn adjusting screw until proper thickness feeler gage can be inserted between valve stem end and rocker arm. Hold adjusting screw and tighten jam nut.

COMPRESSION RELEASE

A manual compression release is located in the rocker arm cover so the exhaust valve can be held open to aid starting. Exhaust valve should be lowered approximately 1 mm (0.040 inch) from valve seat when compression release is operated.

CYLINDER HEAD AND VALVE SYSTEM

Do not remove cylinder head when hot as head may deform. To remove rocker arms, unscrew rocker shaft locating pin (21–Fig. L1-5) on Models 3LD450, LDA450, 3LD510, LDA510, 3LD510/l and L8 or shaft locating set screw (6) on all other models. Withdraw rocker shaft using a suitable puller. Maximum allowable rocker arm to shaft clearance is 0.1 mm (0.004 inch).

Valve face angle is 45° for intake and exhaust. If valve head margin is less than 0.4 mm (0.016 inch), renew valve. Valve seat angle is 45° and recommended seat width is 1.4-1.6 mm (0.055-0.065 inch). Renewable valve seat inserts are used on intake and exhaust. When installing new inserts, cylinder head should first be heated in an oven to 160°-180°C (320°-355°F).

With valves installed, measure distance valve head is recessed from cylinder head mounting surface. Intake valve should be recessed 0.60-0.80 mm (0.024-0.031 inch) on Models 3LD450, LDA450, 3LD510, LDA510, 3LD510/L and L8 or 0.65-0.85 mm (0.026-0.033 inch) on all other models. Exhaust valve (except models with decompression) should be recessed 0.55-1.05 mm (0.022-0.041 inch) on Models 3LD450, LDA450, 3LD510, LDA510, 3LD510/L and L8 or 0.45-0.95 mm (0.018-0.037 inch) on all other models. On engines equipped with compression release, exhaust valve recession should be 0.55-0.95 mm (0.022-0.037 inch). If recession is less than specified, regrind valve seats. If valve recession exceeds specified limits, renew valve seat insert.

Valve stem diameter is 6.98-7.00 mm (0.2748-0.2756 inch) on Models 3LD450, LDA450, 3LD510, LDA510, 3LD510/L and L8 or 7.98-8.00 mm (0.3142-0.3149 inch) on all other models. Desired valve stem clearance in guides is 0.03-0.08 mm (0.001-0.003 inch) on all models. Valve guides are renewable and oversize guide must be machined to provide a 0.05-0.06 mm (0.0020-0.0023 inch) interference fit in cylinder head bore. The cylinder head should be heated to 160°-180°C (320°-355°F) prior to installing guides. Note locating ring (12–Fig. L1-5) around top of each guide. After installation, inside diameter of guides must be reamed or honed to provide desired valve stem clearance.

Intake and exhaust valve springs are identical. Spring free length should be 45.6 mm (1.795 inches) on Models 3LD450, LDA450, 3LD510, LDA510, 3LD510/L and L8 or 52 mm (2.047 inches) on all other models. Spring pressure should be 160-170 N (36-38 pounds) at a length of 34.2 mm (1.346 inches).

Cylinder head mounting surface must not be deformed more than 0.3 mm (0.012 inch). Cylinder head and block mating surfaces may be lapped to improve fit.

When reinstalling cylinder head, be sure to examine push rod tube seals for damage and renew if needed. Tighten cylinder head nuts evenly using tightening sequence shown in Fig. L1-6. It is recommended that nuts be tightened in steps to a final torque of 50 N·m (37 ft.-lbs.) on Models 3LD450, LDA450, 3LD510, LDA510, 3LD510/L and L8 or 78 N·m (58 ft.-lbs.) on all other models.

INJECTOR

REMOVE AND REINSTALL. To remove injector, first clean dirt from injector, injection line, return line and cylinder head. Disconnect return and injection lines from injector and immediately cap or plug all openings. Unscrew injector retaining nuts and carefully remove injector from head being careful not to lose shims between injector and head.

Tighten injector retainer nuts to a torque of 25 N·m (18 ft.-lbs.). If accessible, measure protrusion of nozzle into combustion chamber. Nozzle tip should extend 2.5-3.0 mm (0.100-0.118 inch) on Models 3LD450 and LDA450; 3.0-3.5 mm (0.118-0.138 inch) on Models 3LD510, LDA510, 3LD510/L and L8; 3.5-4.0 mm (0.138-0.158 inch) on all other models. Adjust position of nozzle by installing 0.5 mm (0.020 inch) shims between injector and cylinder head.

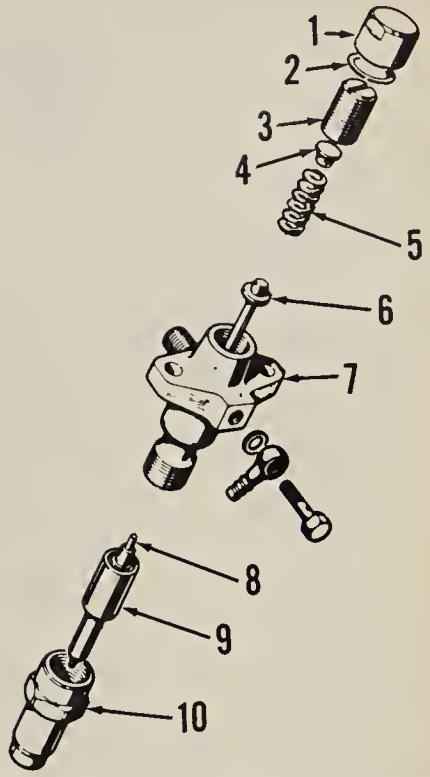


Fig. L1-7—Exploded view of fuel injector assembly.

1. Nut
2. Gasket
3. Adjuster
4. Spring seat
5. Spring
6. Push rod
7. Body
8. Needle
9. Nozzle valve
10. Nozzle nut

TESTING. A suitable test stand is required to check injector operation. Only clean, approved testing oil should be used to test injector. When operating properly, injector nozzle will emit a buzzing sound and should cut off quickly with no fluid leakage at nozzle valve seat.

WARNING: Fuel leaves the injector nozzle with sufficient force to penetrate the skin. When testing, keep yourself clear of nozzle spray.

Nozzle opening pressure should be 18635-19615 kPa (2705-2845 psi). Opening pressure is adjusted by turning adjuster screw (3–Fig. L1-7). Nozzle valve should not show leakage at orifice spray holes for 10 seconds with pressure maintained at 2100 kPa (300 psi) below opening pressure. Spray pattern should be even and well atomized. If pattern is wet, ragged or intermittent, nozzle must be overhauled or renewed.

OVERHAUL. Refer to exploded view of Fig. L1-7. When disassembling injector, protect polished parts from damage. Thoroughly clean parts in a suitable solvent. Clean inside orifice end of nozzle valve with wooden cleaning stick. The

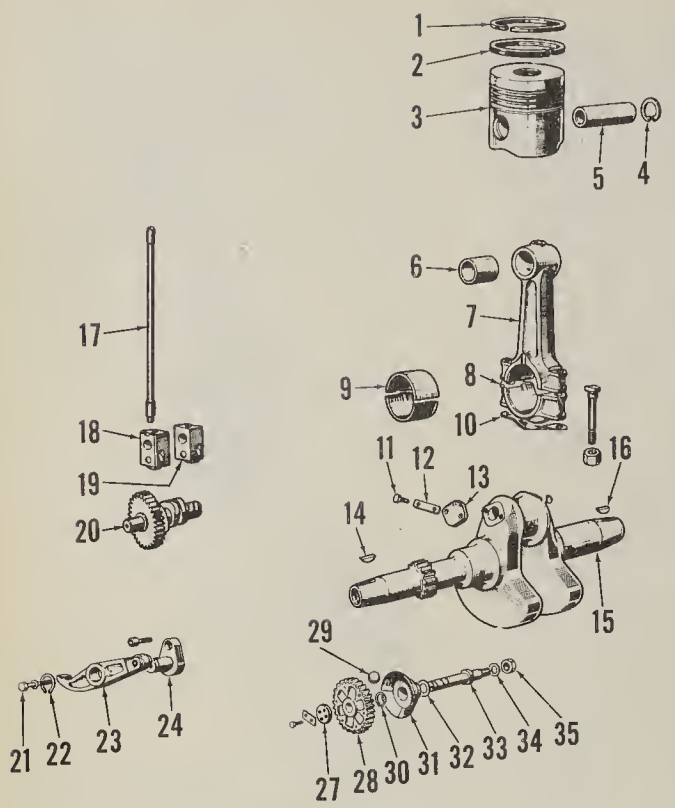


Fig. L1-8—Exploded view of crankshaft, governor and camshaft assemblies. Some models use flyweights instead of flyballs as shown.

1. Compression piston rings (3)
2. Oil control ring
3. Piston
4. Snap rings
5. Piston pin
6. Bushing
7. Connecting rod
8. Rod cap
9. Rod bearing
10. Lockplate
11. Screw
12. Lockplate
13. Plate
14. Key
15. Crankshaft
16. Key
17. Push rods
18. Exhaust cam follower
19. Intake cam follower
20. Camshaft
21. Screw
22. Snap ring
23. Rocker arm
24. Stud
27. Plate
28. Gear
29. Governor balls (6)
30. Snap ring
31. Cup
32. Washer
33. Governor shaft
34. Washer
35. Nut

orifice spray holes may be cleaned by inserting a cleaning wire slightly smaller that the 0.28 mm (0.011 inch) diameter holes.

When reassembling injector, make certain all parts are clean and wet with diesel fuel. Nozzle valve needle (8) must slide freely in valve body (9). If needle valve sticks, reclean or renew nozzle valve assembly.

INJECTION PUMP

Refer to Fig. L1-3 for an exploded view of injection pump. To remove pump, disconnect fuel lines. Plug all openings to prevent entry of dirt. Remove retaining screws and lift out pump. Be sure to retain pump mounting gaskets for use in reassembly. Pump timing is adjusted by changing gasket thickness.

The injection pump should be tested and serviced only by a shop qualified in diesel fuel injection repair.

When reinstalling pump, assemble correct thickness of mounting shim gaskets and be sure to engage control rack pin with governor arm. Tighten retaining screws to a torque of 25 N·m (18 ft.-lbs.). Refer to MAINTENANCE section to check injection timing.

PISTON AND ROD UNIT

REMOVE AND REINSTALL. Piston and connecting rod may be removed after removing cylinder head and oil pan.

When reinstalling piston and rod, note that depression in piston crown is closer to one side of piston. Install piston so depression side of piston is nearer injector side of engine. Some pistons also have an arrow embossed in top of piston so arrow is pointing towards intake side of engine.

Install cap on connecting rod so bearing tang grooves are on the same side. Tighten rod bolts to a torque of 30 N·m (22 ft.-lbs.) on Models 3LD450, LDA450, 3LD510, LDA510, 3LD510/L and L8 or 45 N·m (33 ft.-lbs.) on all other models.

PISTON, PIN AND RINGS

The piston is equipped with three compression rings and one oil control ring. The top compression ring is chrome plated.

Ring end gap should be measured with ring positioned squarely in cylinder. On Models 3LD450, LDA450, 3LD510, LDA510, 3LD510/L, L8, 4LD640, LDA96, 4LD640/L and L10, compression ring end gap should be 0.30-0.50 mm (0.011-0.020 inch). On all other models, compression ring end gap should be 0.40-0.65 mm (0.016-0.025 inch). Oil control ring end gap should be 0.25-0.50 mm (0.010-0.020 inch) on Models 3LD450, LDA450, 3LD510, LDA510, 3LD510/L and L8 or 0.30-0.60 mm (0.011-0.023 inch) on all other models.

To check piston ring groove wear, install new rings onto piston and check clearance between top of ring and top of groove. Renew piston if ring side clearance exceeds specified values as follows: 0.11-0.15 mm (0.004-0.006 inch) for top ring, 0.06-0.10 mm (0.002-0.004 inch) for second and third rings and 0.05-0.10 mm (0.002-0.004 inch) for oil control ring.

Refer to table in Fig. L1-9 for standard piston diameter and desired piston clearance in cylinder bore. Piston diameter is measured at bottom of skirt perpendicular to piston pin bore. Renew piston if wear exceeds 0.05 mm (0.002 inch). Pistons and rings are available in standard size and oversizes of 0.5 mm (0.020 inch) and 1.0 mm (0.040 inch).

Piston diameter is 22.995-23.000 mm (0.9053-0.9055 inch) on Models 3LD450, LDA450, 3LD510, LDA510, 3LD510/L and L8. On all other models, pin diameter is 27.995-28.000 mm (1.1022-1.1023 inches). Piston pin clearance in rod bushing should be

Fig. L1-9—Refer to chart for standard piston diameter and desired piston clearance in cylinder bore.

MODEL	PISTON O.D.	PISTON CLEARANCE
3L0450, L0A450	84.87 - 84.90 mm (3.341 - 3.342 in.)	0.10 - 0.15 mm (0.004 - 0.006 in.)
3L0510, LDA510	84.87 - 84.90 mm (3.341 - 3.342 in.)	0.10 - 0.15 mm (0.0D4 - 0.006 in.)
3L0510/L, L8	84.87 - 84.90 mm (3.341 - 3.342 in.)	0.10.- 0.015 mm (0.004 - 0.006 in.)
4L0640, L0A96	94.85 - 94.87 mm (3.734 - 3.735 in.)	0.13 - 0.17 mm (0.005 - 0.007 in.)
4LD640/L, L10	94.85 - 94.87 mm (3.734 - 3.735 in.)	0.13 - 0.17 mm (0.005 - 0.007 in.)
4L0705, LDA100	99.82 - 99.83 mm (3.9299 - 3.9303 in.)	0.17 - 0.20 mm (0.007 - 0.008 in.)
4L0820, L0A820	101.84 - 101.86 mm (4.009 - 4.010 in.)	0.14 - 0.18 mm (0.0055 - 0.007 in.)
4L0820/L, L14	101.84 - 101.86 mm (4.009 - 4.010 in.)	0.14 - 0.18 mm (0.0055 - 0.007 in.)

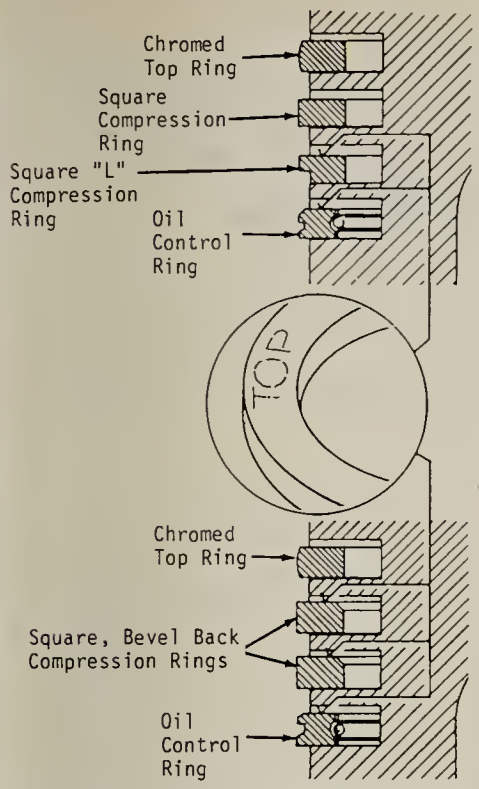


Fig. L1-10—Cross section view showing correct installation of different styles of piston rings.

0.020-0.035 mm (0.0008-0.0014 inch). Maximum allowable clearance is 0.07 mm (0.003 inch). Pin is a thumb push fit in piston.

When installing rings onto piston, stagger ring end gaps 180° apart. Be sure no end gaps are in line with piston pin bore. Refer to Fig. L1-10 for correct installation of rings on piston.

CONNECTING ROD

The connecting rod small end is fitted with a renewable bushing. Clearance between piston pin and connecting rod bushing should be 0.020-0.035 mm (0.0008-0.0014 inch). Maximum allowable clearance is 0.07 mm (0.003 inch).

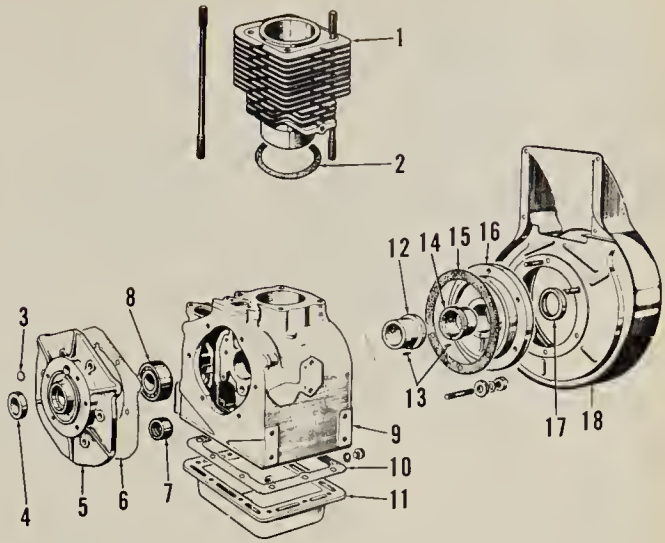
A precision, insert type bearing is used in big end of connecting rod. Desired rod bearing clearance is 0.030-0.065 mm (0.0012-0.0025 inch) for Models 3LD450, LDA450, 3LD510, LDA510, 3LD510/L and L8 or 0.050-0.060 mm (0.0020-0.0023 inch) for all other models. Bearings are available in standard and undersizes.

CYLINDER

All models are equipped with a removable cylinder (1–Fig. L1-11). Standard cylinder diameter is 85.00-85.02 mm (3.346-3.347 inches) on Models 3LD450, LDA450, 3LD510, LDA510, 3LD510/L and L8; 95.00-95.02 mm (3.740-3.741 inches) on Models 4LD640, LDA96, 4LD640/L and L10; 100.00-100.02 mm (3.937-3.938 inches) on Models 4LD705 and LDA100; 102.00-102.02 mm (4.0157-4.0165 inches) on Models 4LD820, LDA820, 4LD820/L and L14. If taper or wear exceeds 0.1 mm (0.004 inch), rebore cylinder to an appropriate oversize.

With piston at top dead center, top of piston should be 0.75-0.90 mm (0.030-0.035 inch) below top surface of cylinder on Models 3LD450, LDA450, 3LD510, LDA510, 3LD510/L and L8 or 0.85-1.0 mm (0.034-0.039 inch) on all other models. Cylinder height is adjusted by varying cylinder mounting shim gaskets (2–Fig. L1-11).

Fig. L1-11—Exploded view of typical crankcase.
1. Cylinder
2. Shim gasket
3. Plug
4. Seal
5. Pto bearing support
6. Gasket
7. Bearing
8. Bearing
9. Crankcase
10. Gasket
11. Oil pan
12. Main bearing
13. Dowel pins
14. Main bearing
15. Shim gasket
16. Main bearing support
17. Seal
18. Air shroud



TIMING GEARS

Gears are accessible after removing pto bearing support (5–Fig. L1-11). Crankshaft and camshaft gears are embossed with marks (M–Fig. L1-12) which should be aligned as shown. If crankshaft and camshaft gears are not marked, proceed as follows: If not previously removed, remove cylinder head, push rod tube and push rods. Position crankshaft so piston is at top dead center. Intake valve cam follower (nearer cylinder) should be opening (rising) and exhaust valve cam follower should be closing (going down). Both cam followers should be same height above crankcase when piston is at top dead center. If not, refer to CAMSHAFT section and remove camshaft, then reinstall camshaft so it is correctly timed with crankshaft. Mark crankshaft and camshaft gears for future reference.

CAMSHAFT, CAM FOLLOWERS AND PUSH RODS

To remove camshaft, first remove cylinder head, push rod tubes, push rods, cam followers and fuel injection pump. Remove pto bearing support (5–Fig. L1-11) and withdraw camshaft.

Inspect camshaft for excessive wear or other damage. Diameter of camshaft bearing journals is 17.96-17.98 mm (0.707-0.708 inch). Height of injection pump lobe should be 31.51 mm (1.240 inches). Height of intake lobe should be 33.95-34.05 mm (1.337-1.340 inches) on early models while intake lobe on late models is 33.68-33.78 mm (1.326-1.330 inches). Exhaust lobe height should be 33.45-33.55 mm (1.317-1.320 inches) on all models. If wear exceeds 0.1 mm (0.004 inch) on camshaft journals or lobes, renew camshaft.

Reassembly is the reverse of disassembly. Be certain timing marks (Fig. L1-12) on camshaft gear are aligned with mark on crankshaft gear. Camshaft end play should be 0.20-0.40 mm (0.008-0.016 inch). End play is adjusted by changing thickness of pto bearing support mounting gasket (6–Fig. L1-11). Note that cam follower rollers are offset to one side of holder and notched sliding surface is on opposite side of holder. Install cam followers so notched surfaces are together and intake cam follower is closer to cylinder barrel.

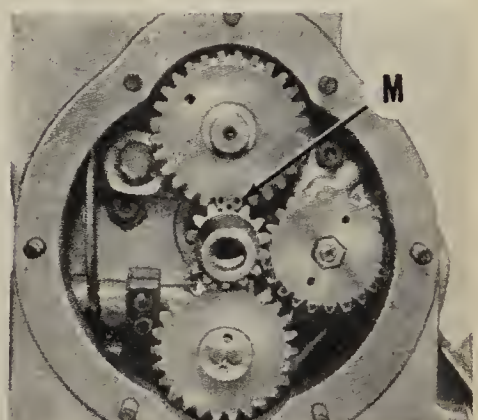


Fig. L1-12—View showing location of timing marks (M) on crankshaft and camshaft gears.

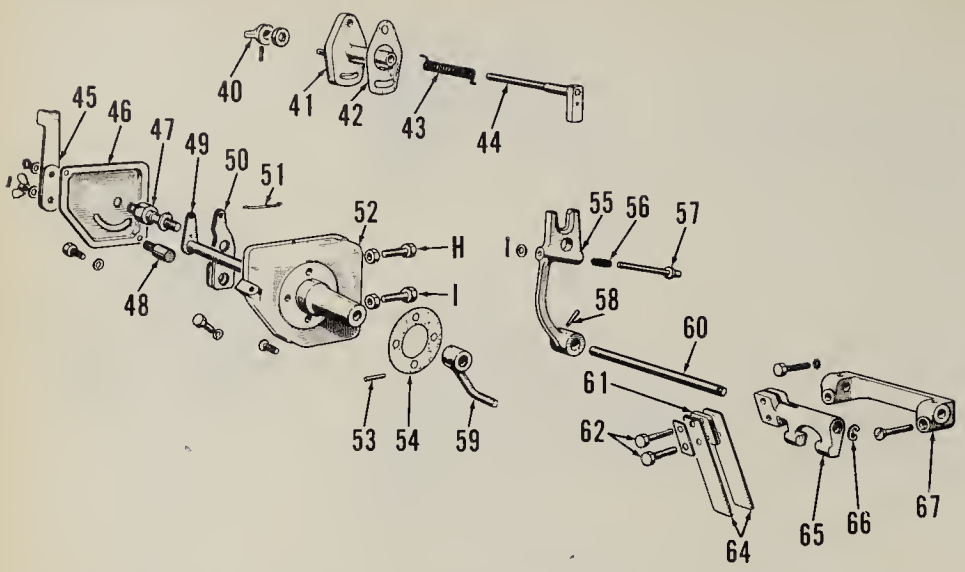


Fig. L1-13—Exploded view of governor and control linkage. Governor fork (65) contacts governor cup (31—Fig. L1-8).

40. Stop knob
41. Plate
42. Gasket
43. Spring
44. Stop arm
45. Throttle lever
46. Cover
47. Stud
48. Pivot screw
49. Arm
50. Lever
51. Link
52. Housing
53. Pin
54. Gasket
55. Arm
56. Spring
57. Torque control rod
58. Pin
59. Arm
60. Shaft
61. Spacer
62. Screws
64. Spring plates
65. Fork
66. "E" ring
67. Bracket
I. Low idle speed screw
H. High speed screw

GOVERNOR

Most models are equipped with flyball type governor while some models may be equipped with flyweights. The governor shaft is shown in Fig. L1-8 while governor linkage is shown in Fig. L1-13. The crankshaft rotates flyball assembly (G – Fig. L1-14) which bears against fork (65 – Fig. L1-13). As the flyballs move, the shaft attached to the fork is rotated thereby moving governor arm (55). Arm (55) mates with fuel injection control rack pin to regulate fuel flow. Throttle lever (45) operates through governor spring plates (64) to control engine speed.

To stop engine, stop knob (40) is turned counterclockwise which forces governor arm to move fuel injection pump control rack to no-fuel position. All models except 3LD510/L, L8, 4LD640/L, L10, 4LD820/L and L14 are equipped with a torque control rod (57) and spring (56) which allows the governor arm (59) additional movement for additional fuel usage under high torque load. By pulling stop knob (40) away from engine, stop arm (44) will slide off tip of torque control rod (57) and allow governor arm to move forward so maximum fuel is delivered during starting.

Governor mechanism is accessible after removing pto bearing support (5 – Fig. L1-11), however, the oil pan must be removed for access to nut (35 – Fig. L1-8) so governor shaft can be withdrawn from crankcase. Inspect governor components and renew any which are damaged or excessively worn. Mechanism must move freely for proper governor operation. Tighten governor shaft nut to a torque of 40 N·m (30 ft.-lbs.).

To adjust governor, pto bearing support (5 – Fig. L1-11) and gasket must be removed. Move throttle lever (45 – Fig. L1-13) to full throttle position. Loosen spring plate screws (62), then move governor arm (55) towards crankcase opening and measure distance (G – Fig. L1-15) from pto bearing support mating surface of crankcase to upper part of governor arm. Distance between crankcase surface and governor arm should be 22 mm (0.866 inch) on Models 3LD450, LDA450, 3LD510, LDA510, 3LD510/L and L8 or 28 mm (1.102 inches) on all other models. Retighten spring plate screws (62 – Fig. L1-13).

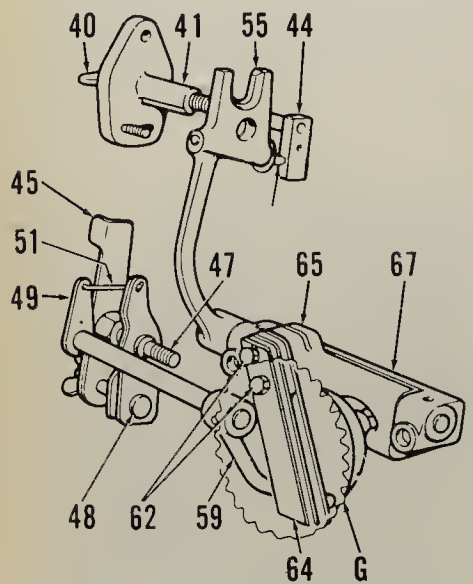


Fig. L1-14—Diagram of governor mechanism. Refer to text and Fig. L1-13 for parts identification.

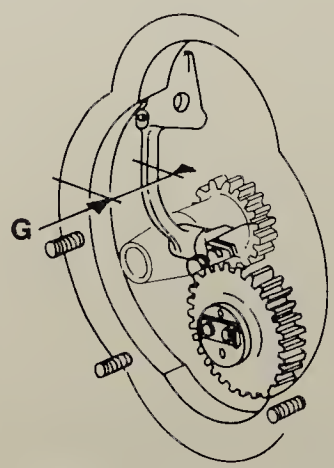


Fig. L1-15—With throttle lever in wide open position, distance (G) from pto bearing support mounting surface to upper part of governor arm should be 22 mm (0.866 inch) on Models 3LD450, LDA450, 3LD510, LDA510, 3LD510/L and L8 or 28 mm (1.102 inches) on all other models. Refer to text.

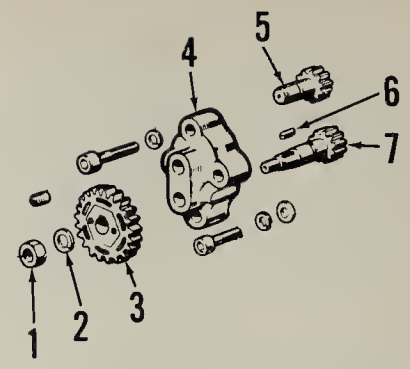


Fig. L1-16—Exploded view of oil pump.

1. Nut
2. Lockwasher
3. Gear
4. Pump body
5. Driven gear
6. Key
7. Drive gear

OIL PUMP AND RELIEF VALVE

R&R AND OVERHAUL. To remove oil pump, remove pto bearing support (5 – Fig. L1-11) and using a suitable puller remove pump gear (3 – Fig. L1-16). Unscrew pump mounting screws and remove pump from crankcase bulkhead. Maximum clearance between gears and pump body should not exceed 0.15 mm (0.006 inch). Maximum clearance between ends of gears and mounting surface of pump body is 0.15 mm (0.006 inch).

Apply a thin coating of sealer to mounting surface of pump body. Install pump and tighten mounting screws to 40 N·m (30 ft.-lbs.). Tighten oil pump

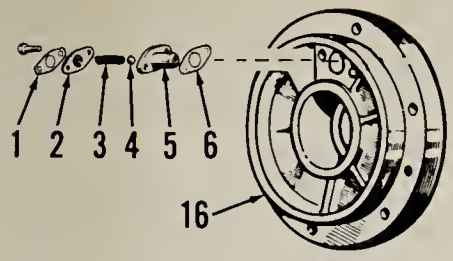


Fig. L1-17 – Exploded view of typical oil pressure relief valve. Some models use a poppet type valve instead of ball (4) and body (5).

1. Lockplate
2. Cover
3. Spring
4. Ball
5. Body
6. Gasket
16. Main bearing gasket

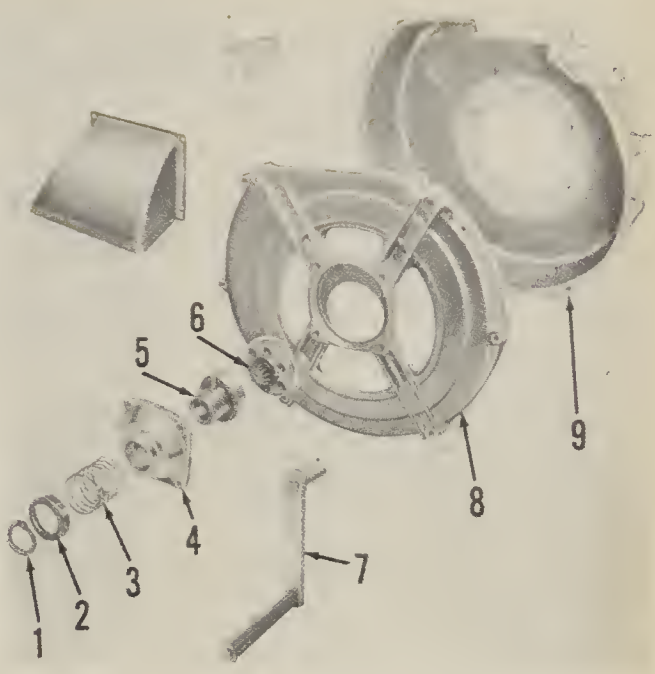


Fig. L1-18 – Exploded view of manual crank starter used on some models.

1. Snap ring
2. Cap
3. Spring
4. Flange
5. Ring gear
6. Pinion
7. Crank
8. Cover
9. Case

gear nut to 20 N·m (15 ft.-lbs.). Install timing gear cover.

The oil pressure relief valve is located on inner face of main bearing support (16 – Fig. L1-17). To remove main bearing support, remove crankshaft pulley or crank starter, flywheel and shroud. Unscrew retaining nuts and remove main bearing support. Inspect pressure relief valve components and renew if damaged or excessively worn. Reinstall relief valve by reversing disassembly procedure. With warm oil, minimum oil pressure should be 75 kPa (11 psi) at idle and 200 kPa (29 psi) at full throttle.

CRANKSHAFT AND BEARINGS

To remove crankshaft, remove crankshaft pulley or crank starter, then remove flywheel. Remove cylinder head, oil pan, piston and connecting rod as previously outlined. Remove pto bearing support (5 – Fig. L1-11) and air shroud (18). Remove main bearing support (16) and withdraw crankshaft from crankcase.

Thoroughly clean crankshaft making sure oil galleries are clear. Inspect for excessive wear and other damage.

Crankshaft main bearing journal standard diameter on Models 3LD450, LDA450, 3LD510, LDA510, 3LD510/L and L8 is 41.99-42.00 mm (1.6531-1.6535 inches) on pto end and 39.99-40.00 mm (1.5744-1.5748 inches) on flywheel end. Main bearings (12 and 14) are available in standard and 1.0 mm (0.040 inch) undersize. New bearings should be installed using a suitable installing tool such as part 7271.3595.047. After installation, check bearing ID and ream bearing to obtain recommended clearance of 0.04-0.06 mm (0.0016-0.0023 inch). Maximum allowable bearing clearance is 0.10 mm (0.004 inch).

On Models 4LD640, LDA96, 4LD640/L, L10, 4LD705, LDA100, 4LD820, 4LD820/L and L14, crankshaft main bearing journal standard diameter

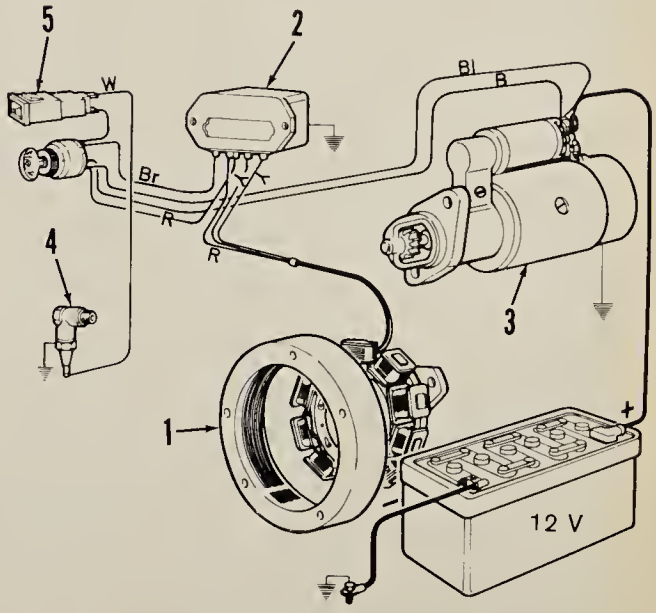


Fig. L1-19—Wiring schematic for models equipped with internal alternator and electric starter.

1. Alternator
2. Regulator
3. Starter motor
4. Oil pressure switch
5. Oil pressure light

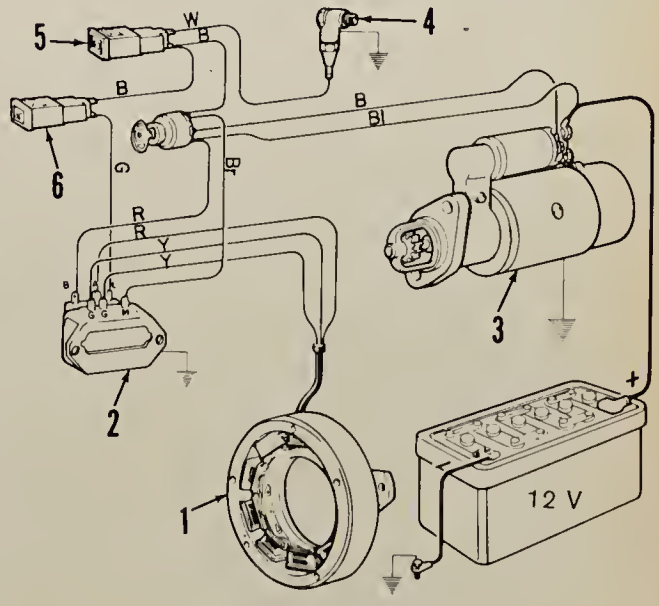


Fig. L1-20—Wiring schematic for models equipped with internal alternator and electric starter using an alternator warning light (6). Refer to L1-19 legend.

is 44.99-45.00 mm (1.7713-1.7716 inches) for both main bearings. Main bearings are available in standard as well as 0.5 mm (0.020 inch) and 1.0 mm (0.040 inch) undersizes which should not require reaming. Recommended main bearing clearance is 0.06-0.08 mm (0.0024-0.0031 inch) on Models LDA100, LDA820, L10 and L14. On all other models, recommended main bearing clearance is 0.04-0.06 mm (0.0016-0.0023 inch).

To reinstall crankshaft, reverse the removal procedure. A special installing tool, part 7271.3595.047, is available from manufacturer to install bearing in retainer (16 – Fig. L1-11). Make certain lubrication oil holds in bearing and retainer are aligned. Renew oil seals (4 and 17) and lubricate lip of seals before reinstalling. Crankshaft end play should be 0.10-0.30 mm (0.004-0.012 inch) and is adjusted by varying thickness of bearing support gasket (15). On Models 3LD450, LDA450, 3LD510, LDA510, 3LD510/L and L8, tighten nuts on flywheel side bearing support to 30 N·m (22 ft.-lbs.) and gear train side bearing support to 25 N·m (18 ft.-lbs.) and gear train side bearing support to 40 N·m (30 ft.-lbs.).

MANUAL CRANK STARTER

Some engines are equipped with a crank type manual starter as shown in Fig. L1-18. Starter repair is evident after inspection of unit.

ALTERNATOR AND REGULATOR

Refer to Fig. L1-19 or L1-20 for wiring schematic typical of models equipped with internal alternator and electric starter motor. Note that circuit illustrated in Fig. L1-20 is for models equipped with an alternator warning light and Fig. L1-19 is for models not equipped with a warning light. Voltage regulator is different for the two circuits.

The internal alternator is contained in the flywheel. Rated output is 13.5 amperes. Stator and rotor are available only as a unit assembly.

LOMBARDINI

Model	No. Cyls.	Bore	Stroke	Displ.
5LD675-2, LDA672	2	95 mm (3.740 in.)	95 mm (3.740 in.)	1346 cc (82.1 cu. in.)
5LD825-2, 832	2	100 mm (3.937 in.)	105 mm (4.134 in.)	1648 cc (100.5 cu. in.)
5LD825-2/L, L27	2	100 mm (3.937 in.)	105 mm (4.134 in.)	1648 cc (100.5 cu. in.)
5LD675-3, LDA673	3	95 mm (3.740 in.)	95 mm (3.740 in.)	2019 cc (123.2 cu. in.)
5LD825-3, 833	3	100 mm (3.937 in.)	105 mm (4.134 in.)	2472 cc (150.8 cu. in.)
5LD825-3/L L40	3	100 mm (3.037 in.)	105 mm (4.134 in.)	2472 cc (150.8 cu. in.)
5LD930-3	3	106 mm (4.173 in.)	105 mm (4.134 in.)	2778 cc (169.5 cu. in.)

Engines covered in this section are four-stroke, air-cooled diesel engines. Crankcase and cylinders are cast iron. Cylinder heads are aluminum. Crankshaft rotation is counterclockwise at pto end. Number 1 cylinder is nearest flywheel. Firing order is 1-3-2 on three cylinder models.

MAINTENANCE

LUBRICATION

Recommended engine oil is SAE 10W for temperatures below 0°C (32°F), SAE 20W for temperatures between 0°C (32°F) and 20°C (68°F) and SAE 40 for temperatures above 20°C (68°F). API classification for oil should be CD. Manufacturer recommends renewing oil after every 300 hours of operation. Oil sump capacities are as follows:

Model	Capacity
5LD825-2, 832, 5LD825-2/L, L27	3.5 L (3.7 qts.)
5LD675-2	4.0 L (4.2 qts.)
LDA672	4.5 L (4.7 qts.)
5LD825-3, 833, 5LD25-3/L, L40	5.5 L (5.8 qts.)
5LD675-3	6 L (6.3 qts.)
5LD930-3	6.3 L (6.6 qts.)
LDA673	6.5 L (6.8 qts.)

A renewable oil filter is mounted on side of crankcase. Manufacturer recommends renewing oil filter after every 300 hours of operation (at the same time oil is changed).

All models are equipped with a pressurized oil system. Refer to Fig. L2-1 for a diagram of the lubrication circuit.

ENGINE SPEED ADJUSTMENT

Low idle speed is adjusted by turning idle speed screw (2–Fig. L2-2) located on top of injection pump control linkage housing. Low idle speed should be 900-1000 rpm on two-cylinder models and 700-800 rpm on three-cylinder models.

Maximum governed speed is adjusted by turning high speed screw (3). High idle (no-load) speed should be adjusted to 150 rpm over normal full-load speed to compensate for governor droop during operation. Maximum rated speed under load is normally 2200 rpm on Models 5LD825-2/L, L27, 5LD825-3/L and L40; 2600 rpm on Model 5LD930-3 and 3000 rpm on all other models. Rated speed under load may vary depending upon application.

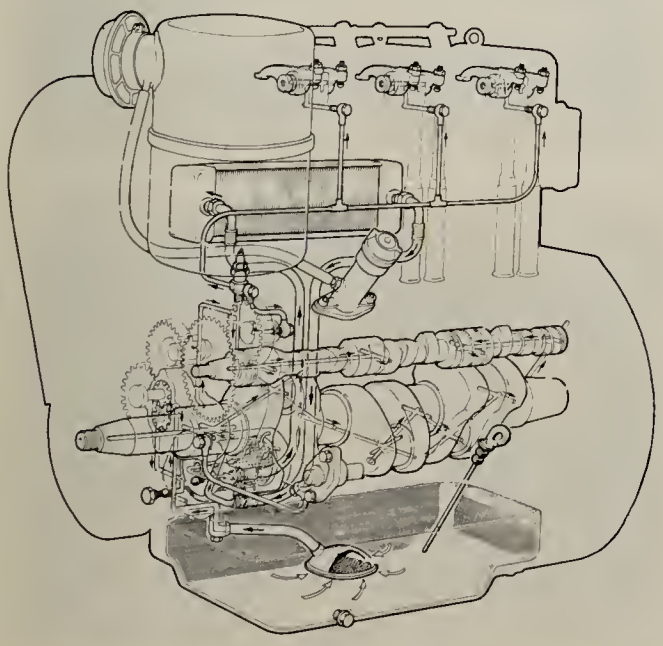


Fig. L2-1—Drawing of lubrication system.

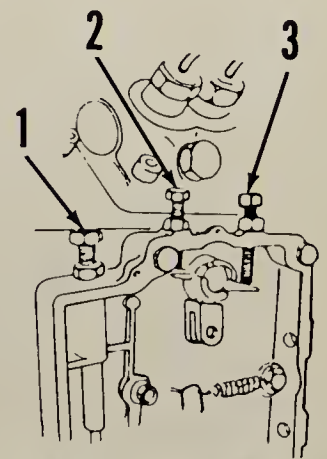


Fig. L2-2—Drawing showing location of low idle adjusting screw (2), high idle adjusting screw (3) and torque control screw (1).

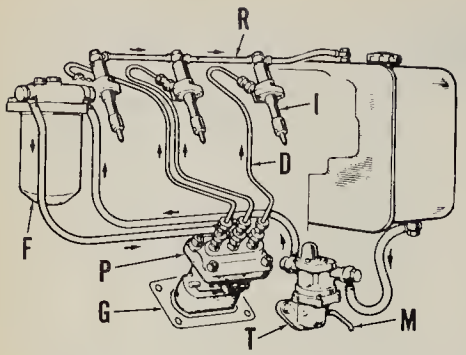


Fig. L2-3—Fuel circuit diagram for three cylinder models. Other models are similar.

D. High pressure delivery line
F. Fuel filter
G. Shim gasket
I. Injector
M. Pump primer lever
P. Fuel injection pump
R. Fuel return line
T. Fuel transfer pump

FUEL SYSTEM

FUEL FILTER. All models are equipped with a single, renewable fuel filter. Manufacturer recommends renewing fuel filter after every 300 hours of operation. However, fuel filter renewal period is more dependent upon fuel quality and cleanliness than length of service or operating conditions. If engine indicates signs of fuel starvation (loss of power or surging), renew filter regardless of hours of operation. After renewing filter, air must be bled from system as outlined in the following paragraph.

BLEED FUEL SYSTEM. To bleed air from fuel system, loosen bleed screw on top of fuel filter mounting housing. Manually actuate fuel transfer pump primer lever (M–Fig. L2-3) until fuel flows from bleeder screw, then tighten screw. Loosen bleeder screw on injection pump. Actuate fuel pump primer lever and retighten bleed screw when a steady flow of fuel is obtained.

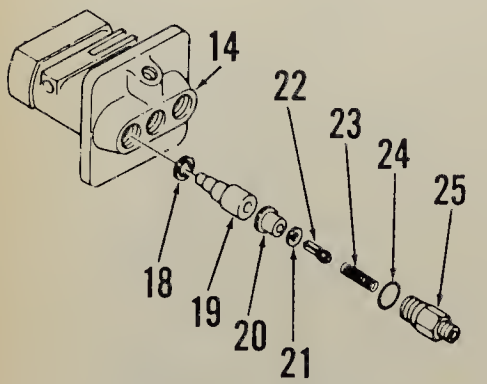


Fig. L2-4—Exploded view of injection pump delivery valve assembly.

14. Pump body
18. Packing
19. Barrel
20. Delivery valve seat
21. Gasket
22. Delivery valve
23. Spring
24. "O" ring
25. Delivery valve holder

If engine fails to start, loosen high pressure line connections at injectors. Rotate crankshaft until fuel emerges from loosened connections. Retighten fuel line connections, then start engine.

INJECTION PUMP TIMING

Beginning of injection should occur at 27°-29° BTDC on Models 832 and 833. On all other models, beginning injection should be at 23°-25° BTDC.

To check injection timing, remove number 1 injection line from injection pump delivery valve holder (25–Fig. L2-4). Unscrew delivery valve holder and remove delivery valve (22) and spring (23). Do not remove valve seat (20). Reinstall delivery valve holder into pump. Place throttle at full speed position. While manually operating fuel transfer pump, turn flywheel in normal direction of rotation so number 1 piston is on compression stroke. Note that fuel should be flowing out of number 1 delivery valve holder. Stop turning flywheel at the exact point fuel ceases to flow from delivery valve. Beginning of injection occurs at this point and timing mark (I–Fig. L2-5 or L2-6) on flywheel bell housing or crankshaft front pulley should be aligned with reference mark (M).

To advance injection timing, remove injection pump and reduce the thickness of pump mounting shim gaskets (G–Fig. L2-3). Increase shim gasket thickness to retard injection timing. Reinstall delivery valve and spring. Tighten injection pump mounting cap screws to a torque of 25 N·m (18 ft.-lbs.). Bleed air from fuel system as previously outlined.

REPAIRS

Refer to the following table for tightening torques.

Camshaft gear	196 N·m (145 ft.-lbs.)
Camshaft retainer	20 N·m (15 ft.-lbs.)
Connecting rod	49 N·m (36 ft.-lbs.)
Crankshaft drive gear	490 N·m (360 ft.-lbs.)
Crankshaft pulley	440 N·m (325 ft.-lbs.)
Cylinder head	88 N·m (65 ft.-lbs.)
Exhaust manifold	20 N·m (15 ft.-lbs.)
Flywheel	345 N·m (255 ft.-lbs.)
Idler gear	137 N·m (100 ft.-lbs.)
Injection pump	25 N·m (18 ft.-lbs.)

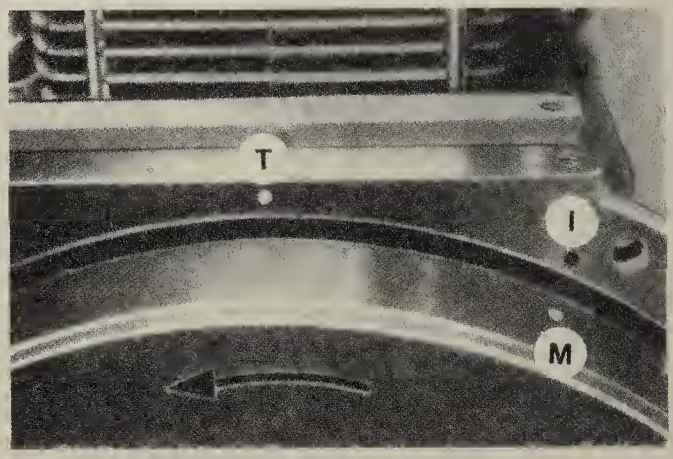


Fig. L2-5—View of timing marks located on flywheel of some models.

I. Injection
M. Reference mark
T. Top dead center

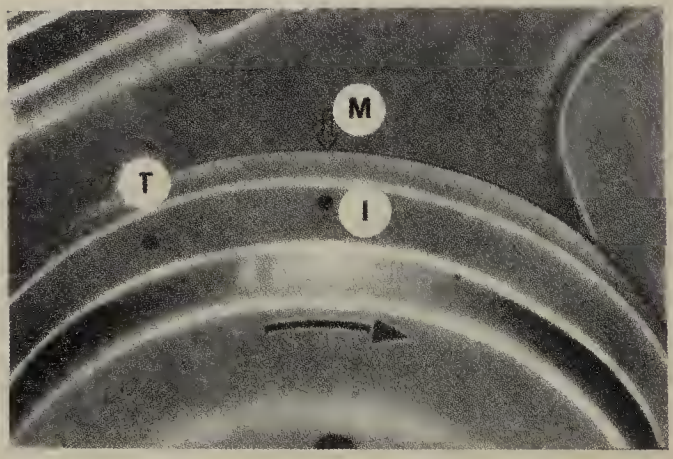


Fig. L2-6—View of timing marks on crankshaft pulley used on some models.

I. Injection
M. Reference mark
T. Top dead center

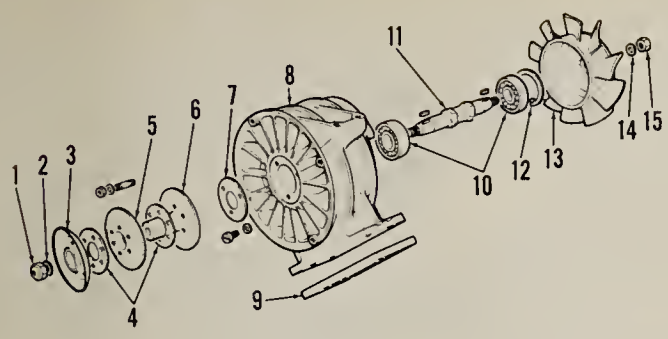


Fig. L2-7—Exploded view of cooling fan. Some models are equipped with two drive belts while others use a single belt.

1. Nut
2. Washer
3. Pulley half
4. Shims
5. Center pulley half
6. Drive pulley half
7. Washer
8. Fan housing
9. Spacer
10. Bearings
11. Shaft
12. Snap ring
13. Fan
14. Washer
15. Nut

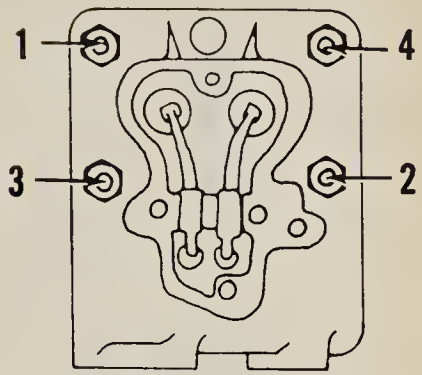


Fig. L2-9—Tighten cylinder head nuts evenly in steps using a crossing pattern. Final torque should be 88 N·m (65 ft.-lbs).

Injector.....20 N·m (15 ft.-lbs.)
Intake manifold.....20 N·m (15 ft.-lbs.)
Main bearing support:
Center.....49 N·m (36 ft.-lbs.)
Flywheel end.....34 N·m (25 ft.-lbs.)
Oil pan.....30 N·m (22 ft.-lbs.)
Oil sump.....40 N·m (30 ft.-lbs.)
Oil pump gear.....60 N·m (45 ft.-lbs.)
Rocker arm cover.....20 N·m (15 ft.-lbs.)
Timing gear cover.....34 N·m (25 ft.-lbs.)

COOLING FAN

All models are equipped with a belt-driven axial cooling fan (Fig. L2-7) to force air around cylinder fins and through the oil cooler (if so equipped). The fan is attached to the fan shroud. The fan housing (8) is mounted on timing gear cover. The internal alternator (on models so equipped) is also mounted within fan housing. Overhaul is evident after inspection of the unit and referral to Fig. L2-7.

VALVE CLEARANCE ADJUSTMENT

Valve clearance should be 0.25-0.30 mm (0.010-0.012 inch) for intake and exhaust valves on all models. Clearance should be adjusted with engine cold. To adjust clearance, remove rocker arm covers and rotate crankshaft until number 1 piston is at TDC on compression stroke. Both valves should be closed (rocker arms loose). Loosen rocker arm adjusting screw locknut, then turn adjusting screw until proper thickness feeler gage can be inserted between rocker arm and end of valve. Hold adjusting screw and tighten locknut. Repeat procedure for remaining cylinders as follows: On two-cylinder engines, turn crankshaft one revolution (360°) to position number 2 piston at TDC on compression stroke. On three-cylinder engines, rotating crankshaft ⅔ turn (240°) will position next piston in firing order (1-3-2) at TDC on compression stroke.

CYLINDER HEAD AND VALVE SYSTEM

Cylinder head should not be removed when engine is hot as head may warp as a result. To remove rocker arms, remove shaft locating set screw (3—Fig. L2-8). Pull rocker shaft (4) from head using a suitalbe puller. A special puller, part 7276.3595.049, is available. Clearance between rocker arm shaft and rocker arms should not exceed 0.1 mm (0.004 inch).

Valve face angle is 45° for intake and exhaust. If valve head margin is less than 0.40 mm (0.016 inch), renew valve. Valve seat angle is 45° and recommended seat width is 1.4-1.6 mm (0.055-0.065 inch). Renewable valve seat inserts are used on intake and exhaust. When installing new inserts, cylinder head should first be heated in an oven to 160°-180°C (320°-355°F).

With valves installed, measure distance valve head is recessed from cylinder head mounting surface. Intake valve should be recessed 0.65-0.85 mm (0.026-0.033 inch) and exhaust valve recession (models not equipped with compression release) should be 0.75-1.25 mm (0.030-0.049 inch). On models equipped with compression release, exhaust valve recession should be 0.55-0.95 mm (0.022-0.037 inch). If valve recession exceeds specified limits, renew seat insert. If recession is less than specified, grind valve seat as necessary.

Valve stem diameter is 8.98-9.00 mm (0.3535-0.3543 inch). Desired valve stem clearance in guide is 0.03-0.08 mm (0.001-0.003 inch). Valve guides are renewable and oversize guides are available. Outer diameter of oversized guides must be machined to provide a 0.05-0.06 mm (0.0020-0.0023 inch) interference fit in cylinder head bores. Prior to installing guides, heat cylinder head to 160°-180°C (320°-355°F). A locating ring around top of guide deter-

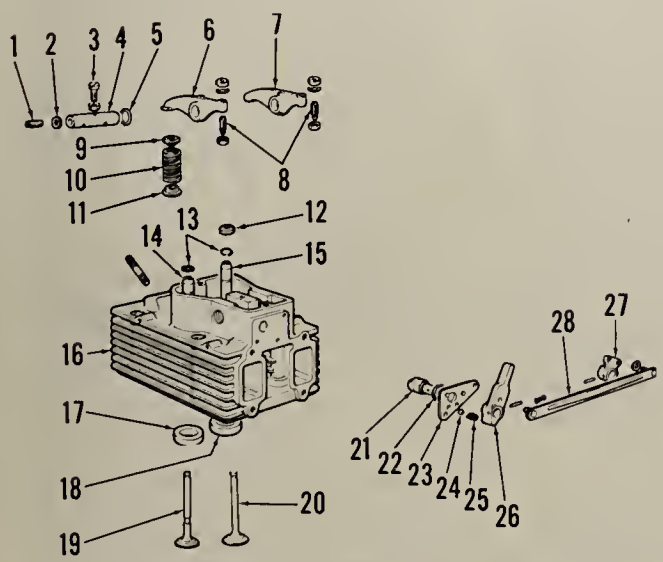


Fig. L2-8—Exploded view of cylinder head assembly.

1. Plug
2. Washer
3. Locating screw
4. Rocker arm shaft
5. Washer
6. Exhaust rocker arm
7. Intake rocker arm
8. Adjuster screw
9. Spring retainer
10. Valve spring
11. Spring seat
12. Seal
13. Snap ring
14. Exhaust valve guide
15. Intake valve guide
16. Cylinder head
17. Exhaust valve seat
18. Intake valve seat
19. Exhaust valve
20. Intake valve
21. Compression release
22. Washer
23. Plate
24. Ball
25. Spring
26. Lever
27. Arm
28. Link

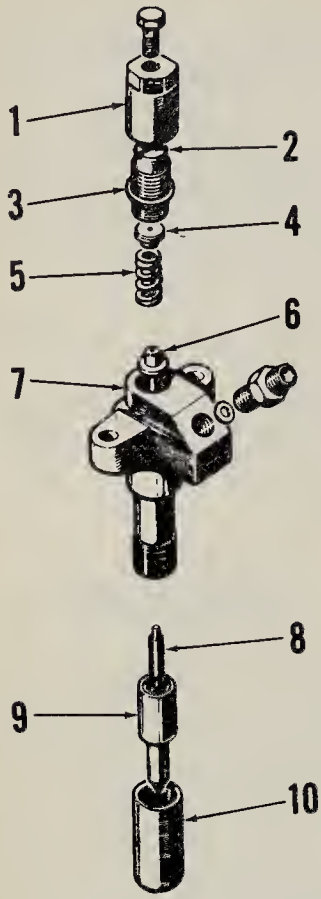


Fig. L2-10—Exploded view of injector.

1. Cap nut
2. Adjusting screw
3. Gasket
4. Spring seat
5. Spring
6. Push rod
7. Body
8. Valve
9. Nozzle
10. Nozzle nut

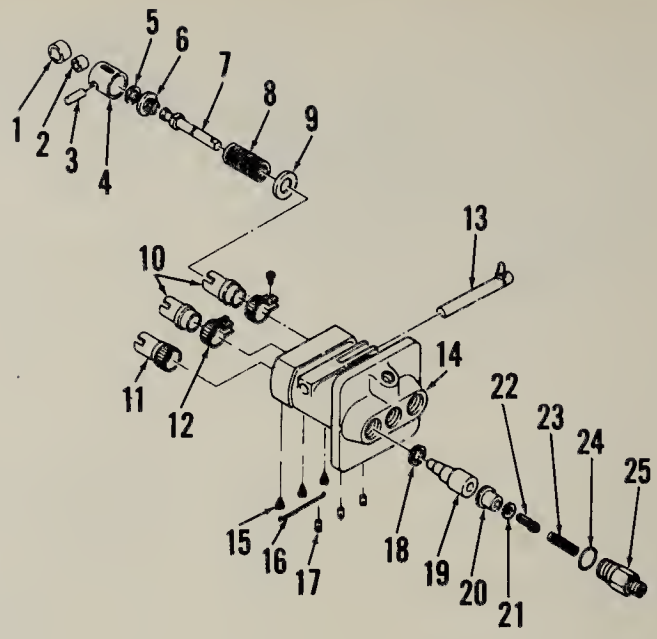


Fig. L2-11—Exploded view of typical fuel injection pump.

1. Outer roller
2. Inner roller
3. Pin
4. Guide
5. Shim
6. Spring retainer
7. Plunger
8. Spring
9. Spring seat
10. Control sleeve B
11. Control sleeve A
12. Sleeve B pinion
13. Control rack
14. Body
15. Guide pins
16. Retaining wire
17. Pins
18. Packing
19. Barrel
20. Delivery valve seat
21. Gasket
22. Delivery valve
23. Spring
24. "O" ring
25. Delivery valve holder

mines installed height of guides. After installation valve guide inside diameter must be reamed or honed to provide desired valve stem clearance.

Intake and exhaust valve springs are identical. Spring free length should be 55.4 mm (2.18 inches). Spring pressure should be 405-428 N (91-96 pounds) at a length of 26.4 mm (1.039 inches).

Before tightening cylinder head nuts, install manifolds so heads are properly aligned with manifolds. Then, tighten cylinder head retaining nuts in 20 N·m (15 ft.-lbs.) steps using a crossing pattern as shown in Fig. L2-9. Final torque should be 88 N·m (65 ft.-lbs.).

INJECTOR

REMOVE AND REINSTALL. To remove injector, first clean dirt from injector, injection line and cylinder head. Disconnect fuel return line and high pressure line and immediately cap or plug all openings. Unscrew injector retaining nuts, then remove injector being careful not to lose shims between injector and cylinder head.

If cylinder head is removed, measure protrusion of nozzle tip beyond combustion chamber surface. Protrusion should be 4.5-5.0 mm (0.177-0.197 inch) and is adjusted by installing shims between injector and cylinder head.

To reinstall injector, reverse the removal procedure. Tighten injector mounting cap screws to a torque of 20 N·m (15 ft.-lbs.).

TESTING. A suitable test stand is required to check injector operation. Only clean, approved testing oil should be used to test injectors.

WARNING: Fuel leaves the injector nozzle with sufficient force to penetrate the skin. When testing, keep yourself clear of nozzle spray.

Connect injector to tester and operate tester lever to purge air from nozzle and make sure nozzle valve is not stuck. When operating, injector nozzle will emit a buzzing sound and should cut off quickly with no leakage at the tip.

Opening pressure should be 20600-21575 kPa (2990-3130 psi). Opening pressure is adjusted by turning adjusting screw (2–Fig. L2-10). Operate tester lever slowly to maintain pressure at 2900 kPa (400 psi) below opening pressure and check for leakage at nozzle tip. If fuel drips from nozzle tip within a 10 second period, nozzle valve must be overhauled or renewed. Operate tester handle to produce 4 to 6 nozzle opening cycles per second and observe spray pattern. Pattern should be evenly distributed and well atomized. If pattern is wet, ragged or intermittent, nozzle must be overhauled or renewed.

OVERHAUL. To disassemble injector, secure nozzle body (7–Fig. L2-10) in a vise with nozzle tip pointing upward. Unscrew nozzle holder nut (10), then remove nozzle valve seat (9) and needle (8). Invert nozzle body and remove cap nut (1), adjusting screw (2), spring seat (4), spring (5) and push rod (6).

Thoroughly clean all parts in a suitable solvent. Protect polished surfaces from scratches or other damage. Clean inside the orifice end of nozzle with wooden cleaning stick. The orifice spray holes may be cleaned by inserting a cleaning wire through the holes. Begin cleaning with a small diameter wire and work up to a wire slightly smaller than the orifice hole inner diameter which is 0.28 mm (0.011 inch).

After cleaning, make certain nozzle needle slides freely in valve body. If needle valve sticks, reclean or renew nozzle assembly. When reassembling injector, make certain all parts are clean and wet with diesel fuel. Adjust opening pressure as outlined in TESTING paragraph.

INJECTION PUMP

Refer to Fig. L2-11 for an exploded view of fuel injection pump. To remove pump, disconnect fuel lines, remove retaining cap screws and lift pump from engine. Retain pump mounting shim gaskets for reassembly as thickness of gaskets determines injection timing.

The injection pump should be tested and overhauled by a shop qualified in diesel fuel injection pump repair.

When reinstalling pump, be sure to engage pin on pump control rack with governor fork. Tighten pump mounting cap screws to a torque of 30 N·m (22 ft.-lbs.). If pump is renewed or overhauled or if original shim gaskets are not used, refer to INJECTION PUMP TIMING paragraph and adjust pump timing.

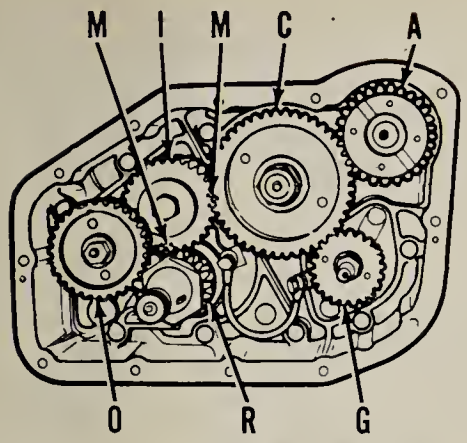


Fig. L2-12—View of timing gears. When correctly timed, marks (M) on idler gear (I) must be aligned with marks on crankshaft gear (R) and camshaft gear (C). Other gears do not require timing.

A. Auxiliary drive gear
C. Camshaft gear
G. Governor gear
I. Idler gear
M. Timing marks
O. Oil pump gear
R. Crankshaft gear

TIMING GEARS

To remove timing gear cover, remove fan belt guard and fan belt. Remove crankshaft pulley using a suitable puller. Remove timing gear cover mounting cap screws and withdraw cover.

Timing gears may be removed after removing gear retaining nuts. Use suitable pullers when removing gears to avoid damage to gears or shafts.

When installing gears, heat crankshaft gear to 180°C (360°F). Drive gear onto crankshaft, then tighten retaining nut to a torque of 490 N·m (360 ft.-lbs.). Install camshaft gear and idler gear making sure timing marks are aligned as shown in Fig. L2-12. Remainder of gears do not require timing.

If gears do not have timing marks, proceed as follows: If not previously removed, remove cylinder head and push rod tubes on number 1 cylinder. Rotate crankshaft so number 1 piston is at top dead center. Rotate camshaft so number 1 cylinder intake valve cam follower is rising and exhaust valve cam follower is going down, then stop rotation when cam followers are at same height above

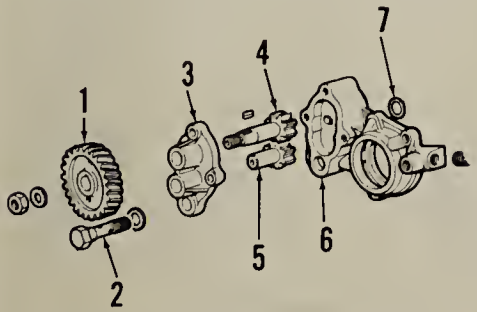


Fig. L2-13—Exploded view of oil pump.

1. Drive gear
2. Special screw
3. Cover
4. Gear & shaft
5. Gear
6. Pump body
7. "O" ring

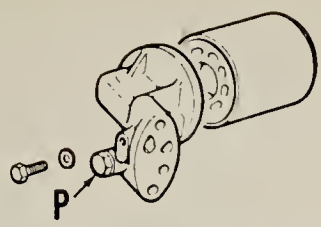


Fig. L2-14—Remove plug (P) for access to oil pressure relief valve in filter adapter.

crankcase surface. Install idler gear and mark contact teeth on crankshaft, idler and camshaft gears for future reference.

Tighten camshaft gear retaining nut to a torque of 195 N·m (145 ft.-lbs.), idler gear nut to 137 N·m (101 ft.-lbs.) and oil pump gear nut to 60 N·m (45 ft.-lbs.).

Inspect front oil seal located in timing gear cover and renew if necessary. Lubricate seal lip before reinstalling cover. Tighten cover retaining screws to a torque of 20 N·m (15 ft.-lbs.). Tighten front pulley retaining nut to 440 N·m (325 ft.-lbs.).

OIL PUMP

R&R OVERHAUL. The oil pump is mounted on the front of the engine and is accessible after removing the timing gear cover. Unscrew pump gear retaining nut, then using a suitable puller, remove pump gear (1–Fig. L2-13). Remove pump cover (3) and gears. Pump housing (6) surrounds the crankshaft and the crankshaft gear must be removed before pump housing can be removed. Note that screw (2) is drilled to allow oil flow through screw.

Oil clearance between oil pump housing and crankshaft should be 0.04-0.08 mm (0.0016-0.0031 inch). Renew pump housing if clearance exceeds 0.13 mm (0.005 inch). Maximum allowable backlash between gears is 0.15 mm (0.006 inch). Maximum allowable clearance between outer diameter of gears and pump housing bore is 0.15 mm (0.006 inch).

Assembly is reverse of disassembly procedure. Tighten pump mounting cap screws to a torque of 40 N·m (30 ft.-lbs.) and pump drive gear retaining nut to 60 N·m (45 ft.-lbs.).

Oil pressure relief valve is located in oil filter housing (Fig. L2-14). Normal oil pressure with oil hot and engine running at 2600 rpm is 285-335 kPa (44-51 psi). Oil pressure may be adjusted by removing plug (P) from filter base and turning adjusting screw.

PISTON AND ROD UNITS

REMOVE AND REINSTALL. Piston and connecting rod may be

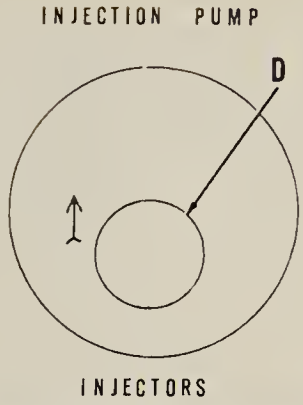


Fig. L2-15—Arrow on piston crown should point towards injection pump and depression (D) should be near injectors.

removed after removing cylinder head and oil pan. Be sure to identify piston and rod assemblies as they are removed so units can be reinstalled in their original locations.

When installing piston and rod, note that depression (D – Fig. L2-15) in piston crown is closer to one side of piston. Install piston so depression will be aligned with injector. Some pistons also have an arrow embossed on piston crown. Properly installed, arrow will point towards the injection pump.

Tighten connecting rod screws to 49 N·m (36 ft.-lbs.). Refer to CYLINDER section and measure piston height in cylinder.

PISTON, PIN AND RINGS

The piston is equipped with three compression rings and one oil control ring. The top compression ring is chrome plated.

Recommended ring end gap is 0.35-0.55 mm (0.014-0.021 inch) for top compression ring, 0.30-0.45 mm (0.012-0.017 inch) for second and third compression rings and 0.25-0.40 mm (0.010-0.015 inch) for oil control ring. Be sure ring is positioned squarely in cylinder bore when checking end gap.

Piston ring side clearance in piston ring groove should be 0.11-0.15 mm (0.004-0.006 inch) for top compression ring, 0.06-0.10 mm (0.002-0.004 inch) for intermediate compression rings and 0.05-0.10 mm (0.002-0.004 inch) for oil control ring. Renew piston if side clearance exceeds recommended values.

Standard piston diameter, measured at bottom of skirt perpendicular to piston pin bore, is 94.82-94.89 mm (3.733-3.736 inches) on Models 5LD675-2, LDA672, 5LD675-3 and LDA673; 105.76-105.78 mm (4.1638-4.1645 inches) on Model 5LD903-3; and 99.82-99.83 mm (3.9299-3.9303 inches) on all other models. Renew piston if wear exceeds

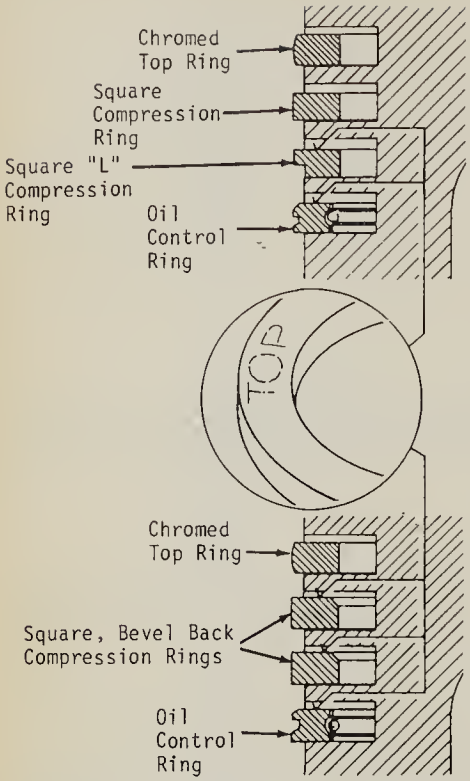


Fig. L2-16—Cross-sectional view of different types of piston rings showing correct installation in piston ring grooves.

0.05 mm (0.002 inch). Pistons are available in standard size as well as oversizes. Weight of each piston must not vary more than 6 grams (0.2 ounce).

Standard piston pin diameter is 31.995-32.000 mm (1.2596-1.2598 inches). Clearance between piston pin and connecting rod bushing should be 0.02-0.03 mm (0.0008-0.0012 inch) and maximum allowable clearance is 0.07 mm (0.0027 inch). Pin should be a thumb push fit in piston.

When installing rings onto piston, stagger ring end gaps 180° apart. Be sure no end gaps are in line with piston pin bore. Refer to appropriate ring installation diagram shown in Fig. L2-16 for proper installation of rings.

CONNECTING ROD

The connecting rod small end is fitted with a renewable bushing. Clearance between piston pin and rod bushing should be 0.02-0.03 mm (0.0008-0.0012 inch) with a maximum allowable clearance of 0.07 mm (0.003 inch).

And insert type bearing is used in connecting rod big end. Desired rod bearing clearance is 0.04-0.07 mm (0.0016-0.0027 inch) with a maximum allowable clearance of 0.10 mm (0.004 inch). Big end bearings are available in standard and undersizes.

Weight of each connecting rod must not vary more than 10 grams (0.35 ounce).

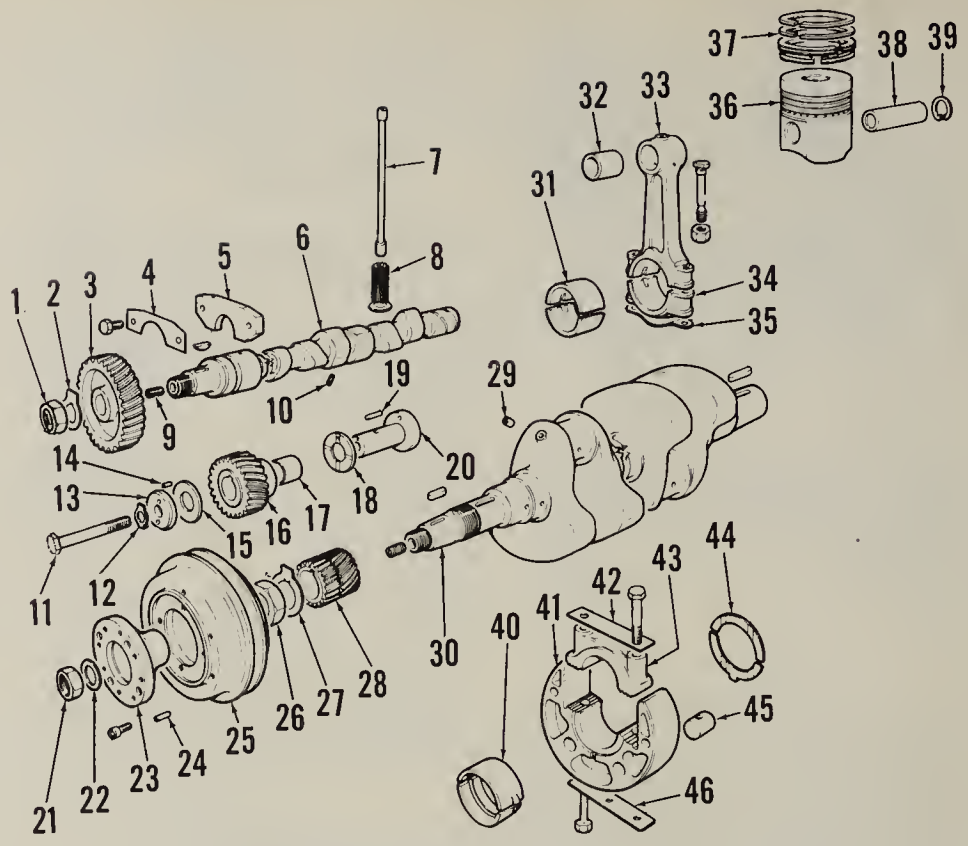


Fig. L2-17—Exploded view of crankshaft, camshaft and idler assemblies.

1. Nut
2. Tab washer
3. Camshaft gear
4. Lockplate
5. Retainer
6. Camshaft
7. Push rod
8. Cam follower
9. Plug
10. Plug
11. Screw
12. Tab washer
13. Spacer
14. Pin
15. Washer
16. Idler gear
17. Bushing
18. Thrust washer
19. Pin
20. Idler shaft
21. Nut
22. Washer
23. Hub
24. Pin
25. Pulley
26. Nut
27. Tab washer
28. Gear
29. Plug
30. Crankshaft
31. Bearing
32. Bushing
33. Connecting rod
34. Rod cap
35. Lockplate
36. Piston
37. Piston rings
38. Piston pin
39. Snap ring
40. Bearing
41. Main bearing support
42. Lockplate
43. Main bearing cap
44. Thrust washer
45. Nut
46. Lockplate

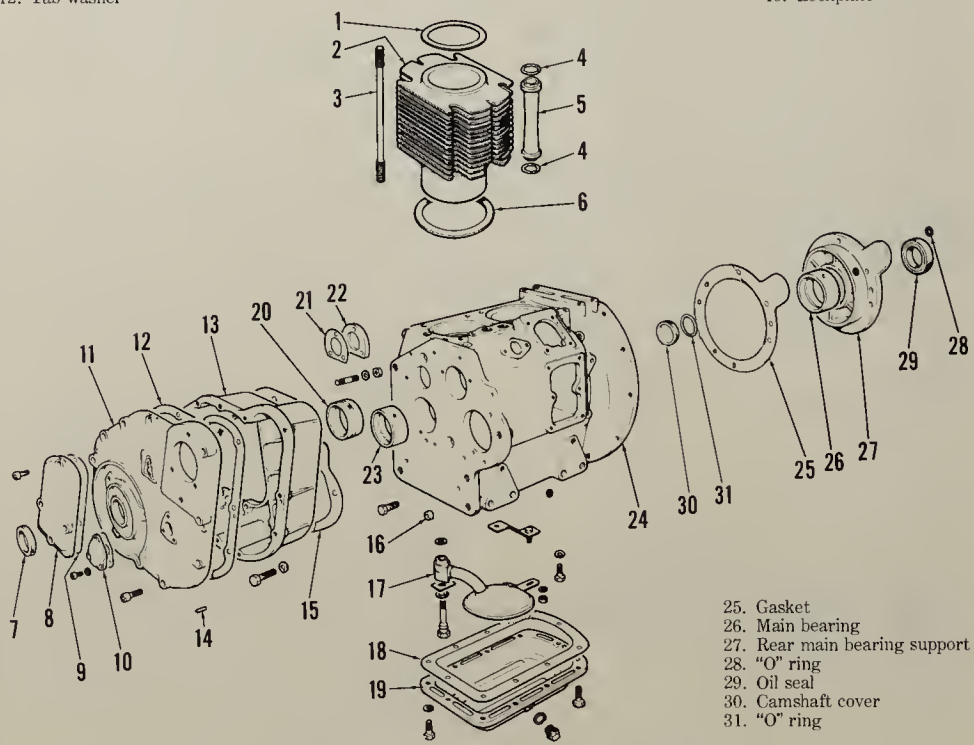


Fig. L2-18—Exploded view of typical crankcase assembly.

1. Head gasket
2. Cylinder
3. Stud
4. Seal
5. Push rod tube
6. Shim gasket
7. Seal
8. Cover
9. Gasket
10. Cover
11. Timing gear cover
12. Gasket
13. Gear housing
14. Pin
15. Gasket
16. Dowel
17. Oil pickup
18. Gasket
19. Oil pan
20. Camshaft bearing
21. Gasket
22. Cover
23. Main bearing
24. Crankcase
25. Gasket
26. Main bearing
27. Rear main bearing support
28. "O" ring
29. Oil seal
30. Camshaft cover
31. "O" ring

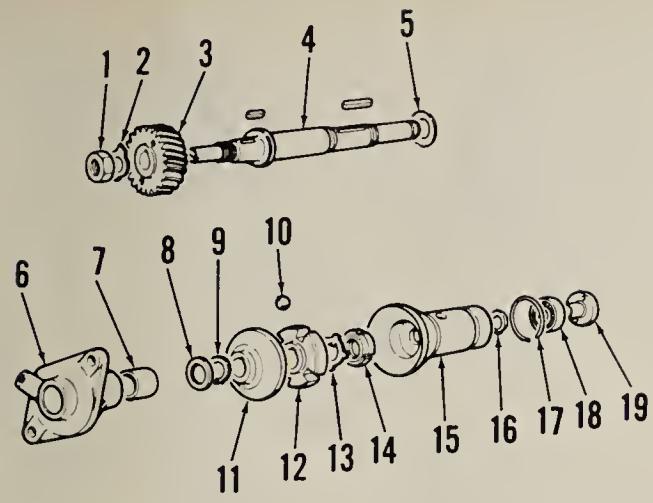


Fig. L2-19—Exploded view of governor shaft.

1. Nut
2. Tab washer
3. Governor shaft
4. Shaft
5. Washer
6. Retainer
7. Bushing
8. Washer
9. Snap ring
10. Balls (4)
11. Ball retainer
12. Ball carrier
13. Tab washer
14. Nut
15. Governor sleeve
16. Snap ring
17. Snap ring
18. Bearing
19. Spindle

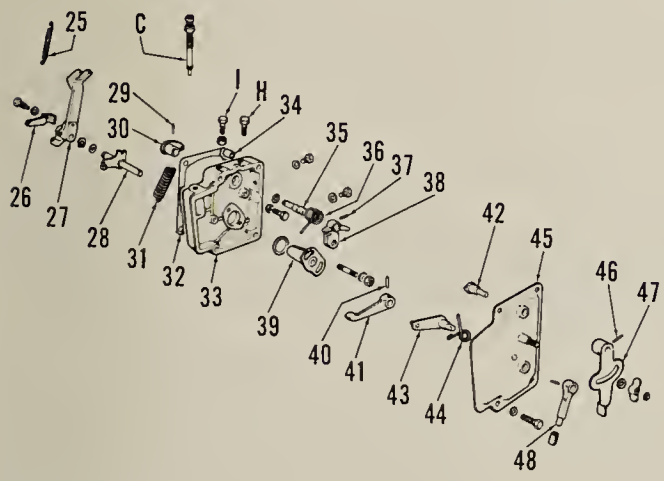


Fig. L2-20—Exploded view of governor and throttle linkage.

C. Torque control screw
H. High idle speed screw
I. Low idle speed screw
25. Start spring
26. Lever
27. Arm
28. Spindle
29. Pin
30. Lever
31. Governor spring
32. Gasket
33. Control housing
34. Dowel
35. Shaft
36. Spring
37. Pin
38. Arm
39. Eccentric
40. Pin
41. Lever
42. Shaft
43. Lever
44. Spring
45. Cover
46. Pin
47. Throttle lever
48. Stop lever

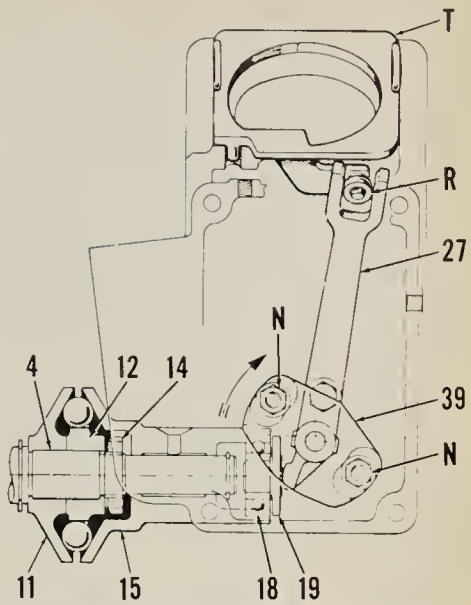


Fig. L2-21—View of governor linkage. Refer to text and Fig. L2-20.

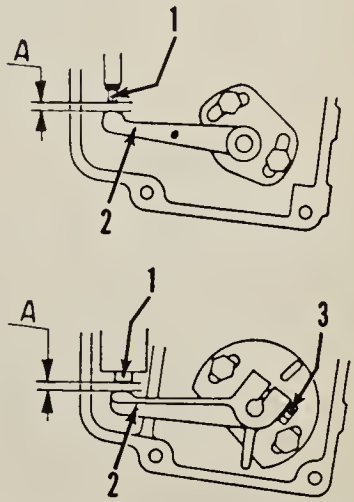


Fig. L2-22—Adjust torque control device to obtain recommended gap (A) between tip of torque control (1) and control lever (2). Refer to text.

1. Torque screw tip
2. Control lever
3. Clamp bolt

CYLINDERS

All models are equipped with removable cylinders. Cylinders may be bored oversize if worn or damaged.

Standard cylinder diameter is 95.00-95.02 mm (3.7401-3.7409 inches) on Models 5LD675-2, LDA672, 5LD675-3 and LDA673; 106.00-106.02 mm (4.1732-4.1740 inches) on Model 5LD930-3; and 100.00-100.02 mm (3.9370-3.9378 inches) on all other models. Cylinder should be rebored to appropriate oversize if taper or out-of-round exceeds 0.1 mm (0.004 inch).

After reinstalling pistons, check piston height in cylinder. With piston at TDC, top of piston should be 0.0-0.1 mm (0.0-0.004 inch) below top surface of cylinder. Piston height is adjusted by installing shim gaskets (6–Fig. L2-18) between cylinder and crankcase.

GOVERNOR

Refer to Figs. L2-19 and L2-20 for exploded view of flyball type governor and control linkage. Governor sleeve (15–Fig. L2-19) slides on governor shaft (4) according to flyball movement and forces spindle (19) to contact governor arm (27–Fig. L2-20). The control rack pin of the fuel injection pump engages the fork in governor arm. The throttle lever (47) operates through governor spring (31) to control engine speed.

The governor shaft assembly (Fig. L2-19) may be removed after removing timing gear cover. Unscrew retainer (6) screws and withdraw governor shaft. Inspect components for excessive wear or damage. Components must move easily without binding. When reinstalling governor shaft, tighten retainer screws to 20 N·m (15 ft.-lbs.).

To synchronize governor linkage with fuel injection pump, remove cover (45–Fig. L2-20) and fuel injection pump. Loosen nuts (N–Fig. L2-21) securing eccentric (39). Install special tool (T), part 7276.2003.004 on two-cylinder models or part 7276.2003.005 on three-cylinder models, in place of injection pump. Be sure tool roller (R-Fig. L2-21) engages fork on governor arm (27). Rotate eccentric (39) until all play is removed from governor but tool roller is still free in fork. Tighten nuts (N), remove tool and reinstall injection pump.

The torque control screw (C-Fig. L2-20) limits movement of governor lever (41) to control maximum fuel delivery under full load. On some models, torque control screw has a spring-loaded tip which allows additional movement of control lever and additional fuel delivery under high torque load. Some early models were equipped with a hydraulically actuated torque control device. When overhauling these

units, manufacturer recommends replacing hydraulic system with the mechanical system by renewing throttle housing assembly. The spring-loaded torque screw must be serviced as a unit assembly. The torque control screw must be matched to the engine setting.

To adjust torque control screw, remove housing cover (45 – Fig. L2-20). While operating engine at high idle (no-load) speed, turn torque control screw as needed to obtain specified gap (A – Fig. L2-22) between tip of screw (1) and control lever (2). On models equipped with hydraulically actuated device, loosen lever clamp bolt (3) and rotate lever to obtain recommended gap (A). Refer to the following table for recommended gap settings.

Model	Gap (A)
5LD675-2, LDA672	2.20-2.25 mm (0.087-0.088 in.)
5LD675-3, LDA673	2.30-2.40 mm (0.090-0.094 in.)
5LD825-2, 832	2.50-2.70 mm (0.098-0.106 in.)
5LD825-2, 832	3.40-3.60 mm (0.134-0.142 in.)
5LD930-3	3.40-3.60 mm (0.134-0.142 in.)

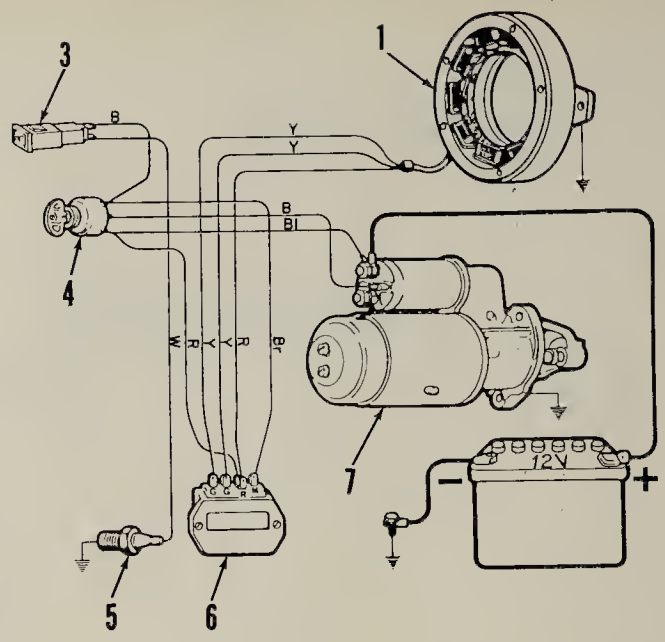


Fig. L2-23—Typical wiring schematic for models equipped with an internal alternator.

1. Alternator
3. Oil pressure light
4. Starting switch
5. Oil pressure switch
6. Regulator
7. Starter

CAMSHAFT

To remove camshaft, first remove cylinder head, timing gear cover and fuel injection pump as previously outlined. Remove camshaft gear using a suitable puller. Remove push rod tubes and push rods, then use suitable tools to hold cam followers in a raised position. Remove fuel transfer pump. Remove camshaft retainer plate (5 – Fig. L2-17), then withdraw camshaft from crankcase. Remove oil pan for access to cam followers. Be sure to identify cam followers so they can be reinstalled in their original positions.

The camshaft front bearing journal operates in a renewable, sleeve bearing (20 – Fig. L2-18) which is pressed into front of crankcase. The camshaft center journal (three-cylinder models) and rear journal (all models) operate directly in unbushed bores in the crankcase.

Camshaft standard bearing journal diameter is 47.94-47.96 mm (1.8874-1.8882 inches) for front journal, 42.92-42.94 mm (1.6898-1.6905 inches) for middle journal (three-cylinder only) and 29.91-29.93 mm (1.1776-1.1783 inches) for rear journal. If clearance between front journal and bushing exceeds 0.2 mm (0.008 inch), renew bushing. Bushing is available in standard as well as undersizes of 0.25, 0.5 and 1.0 mm. After pressing new bushing into crankcase, check inside diameter and ream, if necessary, to provide operating clearance of 0.10-0.14 mm (0.004-0.005 inch).

Camshaft lobe height should be 34.3-34.4 mm (1.3504-1.3543 inches) for both intake and exhaust. Height of injection cam lobes should be 38 mm (1.496 inches).

Camshaft end play is controlled by retainer plate (5 – Fig. L2-17). Desired end play is 0.40-0.70 mm (0.016-0.027 inch). Renew retainer plate if end play exceeds 1.0 mm (0.039 inch).

Inspect face of cam followers for excessive wear, pitting or other damage. Outside diameter of cam followers is 19.96-19.98 mm (0.7858-0.7866 inch). Clearance between cam followers and crankcase bores should be 0.02-0.06 mm (0.0008-0.0023 inch).

When reinstalling camshaft, be sure to lubricate cams and bearing journals. Make certain retaining plate is installed with lubricating grooves facing the crankcase. Tighten retainer plate cap screws to a torque of 20 N·m (15 ft.-lbs.) and camshaft gear retaining nut to 196 N·m (145 ft.-lbs.). Be sure timing marks are aligned as outlined in TIMING GEAR paragraph. If camshaft is renewed, check injection pump timing as outlined in MAINTENANCE section.

CRANKSHAFT AND BEARINGS

To remove crankshaft, first remove cylinder head, oil pan, pistons and rods and timing gear cover. Remove idler gear, oil pump gear and crankshaft gear using suitable pullers. Remove oil pump. Remove nuts securing outer bearing support (27 – Fig. L2-18) and cap screws securing center bearing support (41 – Fig. L2-17). Carefully withdraw crankshaft and center bearing support assembly from crankcase. Separate main bearing cap (43) from bearing support (41).

Crankshaft main bearing journal diameter is 59.94-59.95 mm (2.3598-2.3602 inches) on Models LDA672 and LDA673. On all other models, standard main bearing journal diameter is 64.96-64.98 mm (2.5575-2.5582 inches). Desired main bearing clearance is 0.05-0.08 mm (0.002-0.003 inch) with a maximum allowable clearance of 0.10 mm (0.004 inch). Standard and undersize main bearings are available. Special tool 7271.3595.047 is available from manufacturer to install bearing (26 – Fig. L2-18) in bearing support (27). Be sure lubricating oil holes are aligned.

Standard crankpin journal diameter is 55.34-55.35 mm (2.1787-2.1791 inches). Recommended rod bearing clearance is 0.04-0.07 mm (0.001-0.0027 inch) with a maximum allowable clearance of 0.10 mm (0.004 inch). Standard and undersize bearings are available.

Crankshaft end play is controlled by thrust washer halves (44 – Fig. L2-17) mounted on center support (41) on two-cylinder models, or on support nearest timing gear end of engine on three-cylinder models. Crankshaft end play should be 0.05-0.40 mm (0.002-0.016 inch). Install new thrust washers if end play exceeds 0.5 mm (0.020 inch).

Main bearing cap (43) has a serrated parting face. Install cap in support so reference numbers on cap and support

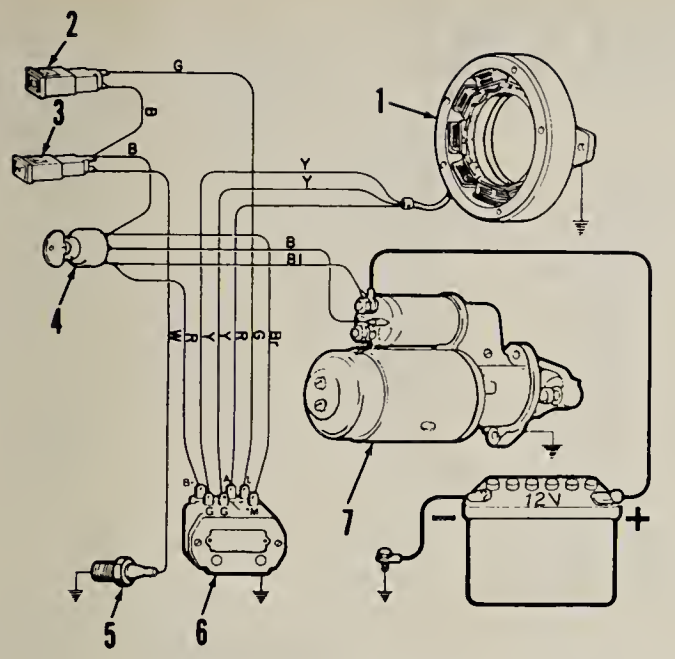


Fig. L2-24—Wiring schematic for models equipped with an alternator warning light (2). Refer to Fig. L2-23.

are on same side. Tighten bearing cap retaining screws to a torque of 49 N·m (36 ft.-lbs.). Reinstall crankshaft, then tighten center support cap screws to 49 N·m (36 ft.-lbs.). Lubricate lip of rear oil seal (29), then reinstall rear bearing plate (27) and tighten nuts to 34 N·m (25 ft.-lbs.). Refer to TIMING GEARS paragraph for correct installation of crankshaft gear. Complete reassembly by reversing the disassembly procedure.

ALTERNATOR AND REGULATOR

Refer to Fig. L2-23 or L2-24 for wiring schematic. Circuit illustrated in Fig. L2-24 uses and alternator warning light and voltage regulator is different than the regulator used in circuit shown in Fig. L2-23 without alternator warning light. Internal alternator (1) is located in blower fan housing.

LOMBARDINI

Model	No. Cyls.	Bore	Stroke	Displ.
6LD260, 500	1	70 mm (2.755 in.)	68 mm (2.677 in.)	262 cc (16 cu. in.)
6LD260/C	1	70 mm (2.755 in.)	68 mm (2.677 in.)	262 cc (16 cu. in.)
6LD325, 520	1	78 mm (3.070 in.)	68 mm (2.677 in.)	325 cc (19.8 cu. in.)
6LD325/C	1	78 mm (3.070 in.)	68 mm (2.677 in.)	325 cc (19.8 cu. in.)
6LD360, 530	1	82 mm (3.228 in.)	68 mm (2.677 in.)	359 cc (21.9 cu. in.)
6LD360/C, 6LD360/V	1	82 mm (3.228 in.)	68 mm (2.677 in.)	359 cc (21.9 cu. in.)
6LD500	1	86 mm (3.385 in.)	68 mm (2.677 in.)	395 cc (24.1 cu. in.)

Engines covered in this section are four-stroke air-cooled diesel engines. "C" series engines have pto drive on camshaft. Model 6LD360/V has crankshaft mounted vertically. On all engines, the cylinder head and cylinder block are aluminum while the cylinder is cast iron.

MAINTENANCE

LUBRICATION

Recommended engine oil is SAE 10W for temperatures below 0°C (32°F), SAE 20W for temperatures between 0°C (32°F) and 20°C (68°F) and SAE 40 for temperatures above 20°C (68°F). API classification for oil should be CD. Oil sump capacity is 0.7 liters (1.5 pints) on Model 6LD360/C, 1.2 liter (2.5 pints) on Model 6LD400 and 1.0 liter (2.1 pints) on all other models.

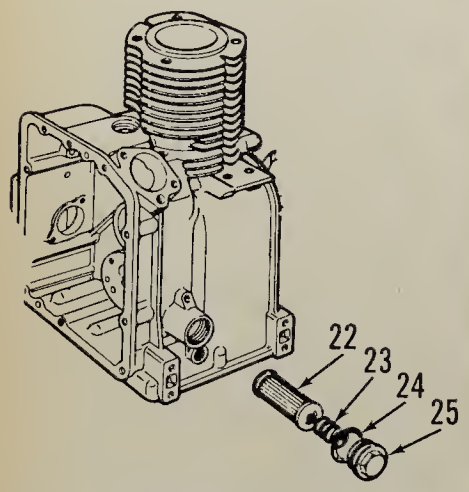


Fig. L3-1—Engine oil filter is located in side of crankcase.

22. Oil filter
23. Spring
24. "O" ring
25. Plug

A renewable oil filter is located on side of engine block (Fig. L3-1). Manufacturer recommends renewing engine oil and filter after every 300 hours of operation.

ENGINE SPEED ADJUSTMENT

Idle speed is adjusted by turning idle speed screw (I–Fig. L3-2). Idle speed should be 1100-1400 rpm on Models 6LD260, 500, 6LD325, 520, 6LD360, 530, and 6LD360/V; 550-700 rpm on Models 6LD260/C, 6LD325/C and 6LD360/C; 900-1000 rpm on Model 6LD400.

Maximum governed speed is adjusted by turning high speed screw (H). Set maximum (no-load) speed 180 rpm above engine rated load speed to compensate for governor droop during operation. Maximum speed under load is normally 3600 rpm for all models except 6LD260/C, 6LD325/C and 6LD360/C which are normally rated at 1800 rpm. Governed speed may vary depending upon engine application.

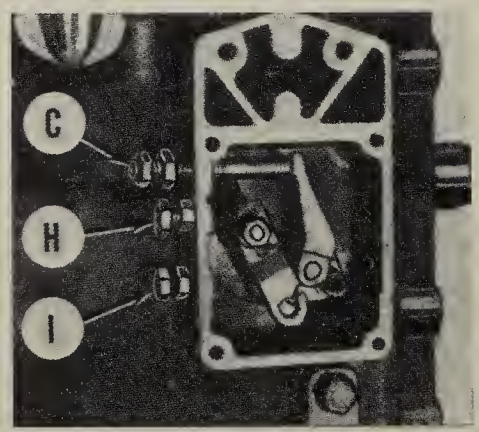


Fig. L3-2—Turn screw (I) to adjust low idle speed and screw (H) to adjust high idle speeed. Refer to text for adjustment of torque control screw (C).

FUEL SYSTEM

FUEL FILTER. The fuel filter may be located inside the fuel tank as shown in Fig. L3-3, or a cartridge type filter as shown in Fig. L3-4 may be used. Fuel

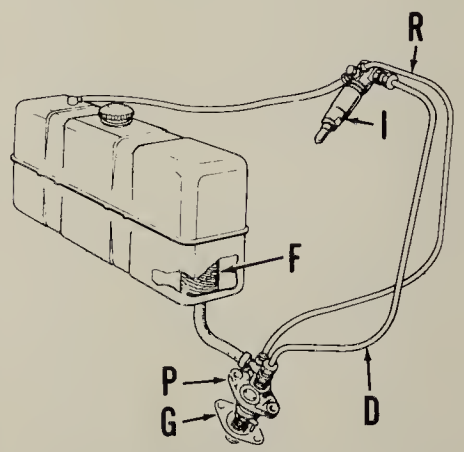


Fig. L3-3—Diagram of fuel system with filter located in tank.

D. High pressure line
F. Fuel filter
G. Shim gasket
I. Injector
P. Injection pump
R. Return line

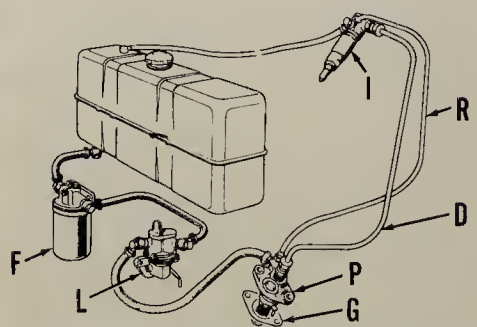


Fig. L3-4—Diagram of fuel system equipped with fuel filter cartridge and fuel transfer pump used on some models.

D. High pressure line
F. Fuel filter
G. Shim gasket
I. Injector
L. Fuel pump
P. Injection pump
R. Return line

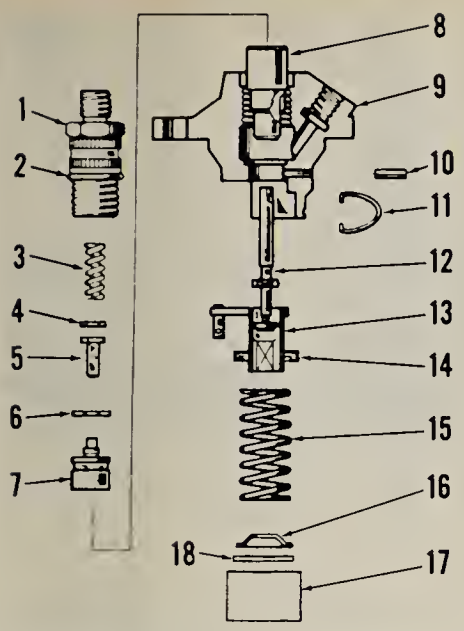


Fig. L3-5—Exploded view of injection pump used on all models. Pump is actuated by engine camshaft.

1. Delivery union
2. "O" ring
3. Spring
4. Washer
5. Delivery valve
6. Gasket
7. Delivery valve seat
8. Barrel
9. Pump body
10. Pin
11. Clip
12. Plunger
13. Control sleeve
14. Spring seat
15. Spring
16. Spring retainer
17. Tappet
18. Spacer

filter should be renewed after every 300 hours of operation or sooner if required. After renewing filter, air must be bled from system as outlined in the following paragraph.

BLEED FUEL SYSTEM. On gravity flow fuel systems (Fig. L3-3), loosen fuel line fitting on injection pump and allow fuel to flow until free of air, then retighten fitting.

On models equipped with cartridge type filter (Fig. L3-4), unscrew bleed screw on filter housing and allow fuel to flow until free of air.

On models equipped with a fuel transfer pump (L–Fig. L3-4), loosen fuel supply line fitting on injection pump. Manually operate fuel pump primer lever until fuel flows from fitting, then retighten fitting.

If engine fails to start after bleeding air from filter and fuel line, loosen high pressure line at injector. Rotate crankshaft to operate injection pump until fuel is discharged at injector line fitting. Retighten injector line and start engine.

INJECTION PUMP TIMING

Injection pump timing is adjusted using shim gaskets (G–Fig. L3-3 and L3-4) between pump body and mounting

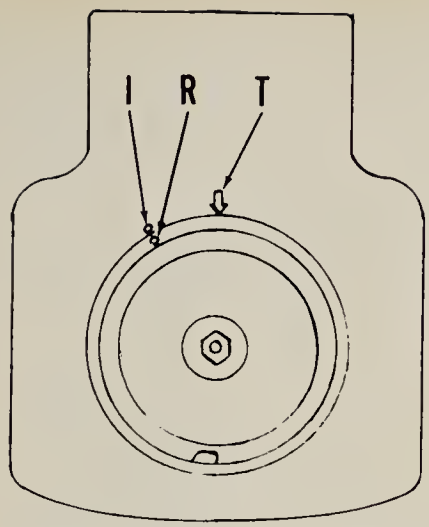


Fig. L3-6—Injection should occur when timing dot (R) of crankshaft pulley is aligned with timing dot (I) on fan shroud. Piston is at TDC when timing dot (R) and mark (T) are aligned.

surface of crankcase. To check pump timing, unscrew injector line (D) fitting from pump delivery union (1–Fig. L3-5). Unscrew delivery union and remove spring (3), washer (4) and delivery valve (5). Do not remove valve seat (7). Reinstall delivery union into pump body. Move throttle control lever to full speed position. Rotate crankshaft in normal direction of rotation so piston is on compression stroke. Note that fuel should flow from delivery union. Stop crankshaft rotation at moment fuel ceases to spill out of union. This is beginning of injection and timing dot (R–Fig. L3-6) on crankshaft pulley should be aligned with injection timing dot (I) on fan shroud.

If fuel stops flowing before timing dots are aligned (timing advanced), add shims under pump. If fuel stops flowing late (timing retarded), reduce thickness of shim gaskets.

After pump timing is properly adjusted, tighten pump mounting cap screws to a torque of 30 N·m (22 ft.-lbs.). Bleed air from system as previously outlined.

REPAIRS

TIGHTENING TORQUES

Refer to the following table for tightening torques.

Connecting rod	34 N·m (25 ft.-lbs.)
Cylinder head	34 N·m (25 ft.-lbs.)
Flywheel	145 N·m (110 ft.-lbs.)
Injection pump	30 N·m (22 ft.-lbs.)
Injector	12 N·m (9 ft.-lbs.)
Main bearing support:	
Flywheel end	30 N·m (22 ft.-lbs.)
Gear train end	44 N·m (26 ft.-lbs.)
Oil pan	25 N·m (18 ft.-lbs.)
Oil pump	12 N·m (9 ft.-lbs.)
Oil pump gear	25 N·m (18 ft.-lbs.)
Rocker arm cover	20 N·m (15 ft.-lbs.)
Timing gear cover	44 N·m (33 ft.-lbs.)

VALVE CLEARANCE ADJUSTMENT

To adjust valve clearance, first remove rocker arm cover and rotate crankshaft until piston is at TDC on compression stroke. Clearance between valve stem end and rocker arm should be 0.15 mm (0.006 inch) for both intake and exhaust with engine cold. Note that there are two adjusting screws (Fig. L3-7) in exhaust rocker arm on models equipped with compression release mechanism. Inner adjusting screw (V) is

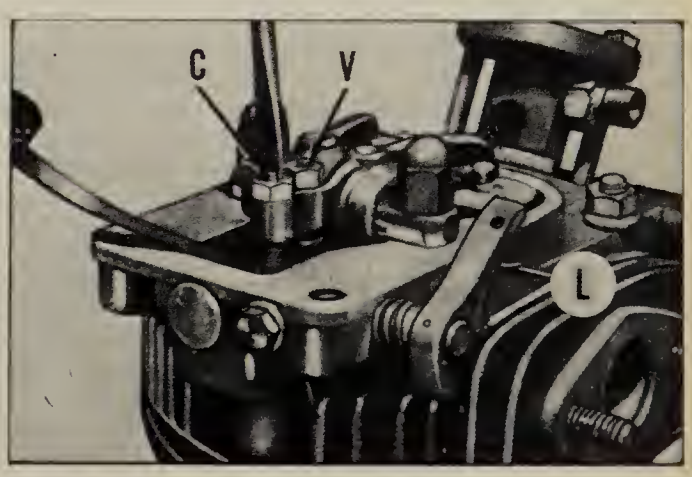


Fig. L3-7—With compression release lever (L) in released position, turn outer adjusting screw (C) so clearance is 0.9-1.1 mm (0.035-0.043 inch) between screw and shaft. Adjusting inner screw (V) on rocker arm determines valve clearance.

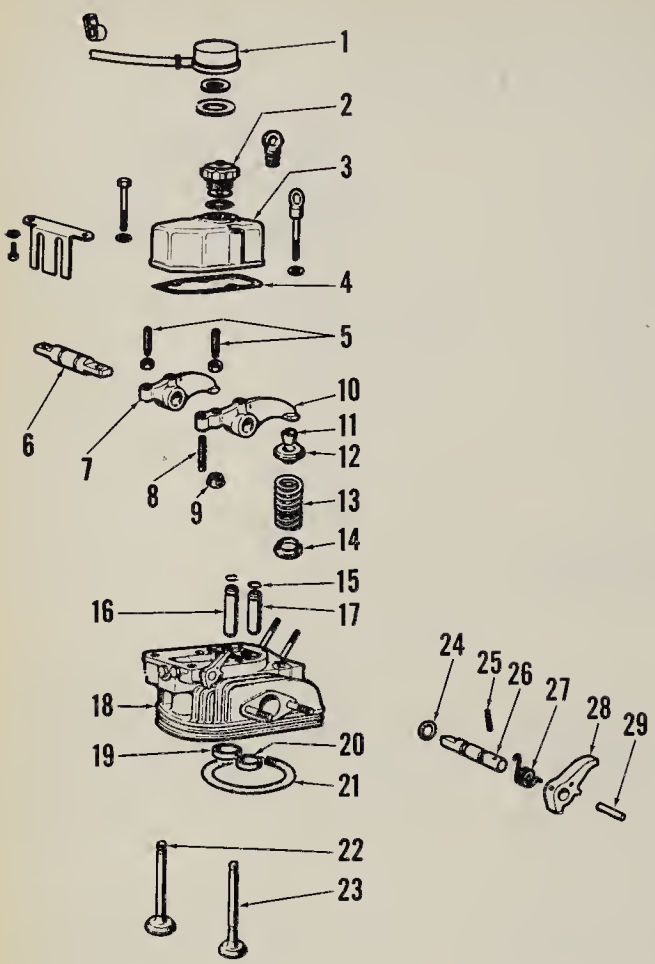


Fig. L3-8—Exploded view of cylinder head assembly.

1. Breather
2. Fill cap
3. Rocker cover
4. Gasket
5. Valve adjusting screws
6. Rocker arm shaft
7. Intake rocker arm
8. Compression release adjusting screw
9. Valve seal
10. Exhaust rocker arm
11. Valve keepers
12. Spring retainer
13. Spring
14. Spring seat
15. Locating rings
16. Intake valve guide
17. Exhaust valve guide
18. Cylinder head
19. Intake valve seat
20. Exhaust valve seat
21. Head gasket
22. Intake valve
23. Exhaust valve
24. "O" ring
25. Pin
26. Compression release shaft
27. Spring
28. Compression release lever
29. Pin

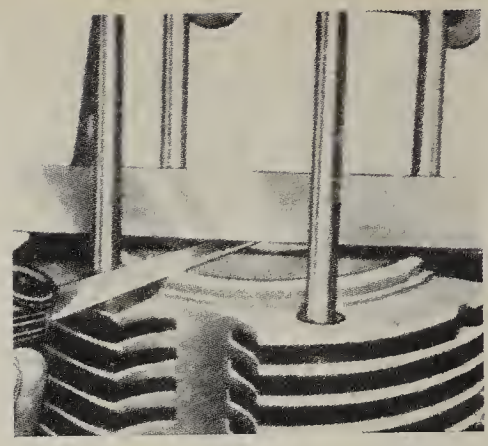


Fig. L3-9—Measure piston height in cylinder and refer to text to determine cylinder head gasket thickness.

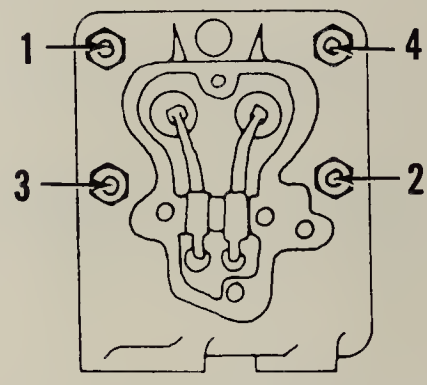


Fig. L3-10—Tighten cylinder head nuts in steps using a crossing pattern.

used to adjust valve clearance while outer screw (C) is used to adjust compression release gap.

COMPRESSION RELEASE

Some models are equipped with a manual compression release so the exhaust valve may be held open to aid starting. Compression release components (24 through 29 – Fig. L3-8) are mounted in the cylinder head. Rotating shaft (26) will force the exhaust rocker arm (10) to slightly open the exhaust valve.

The compression release is adjusted by turning outer adjusting screw (C – Fig. L3-7) in exhaust valve rocker arm. Adjust compression release gap AFTER adjusting exhaust valve clearance. With Compression lever (L) in off position, clearance between adjusting screw and shaft should be 0.9-1.1 mm (0.035-0.043 inch).

Diameter of compression release shaft (26 – Fig. L3-8) is 9.37-10.00 mm (0.369-0.393 inch) while lobe height is 8.45-8.50 mm (0.333-0.334 inch).

CYLINDER HEAD AND VALVE SYSTEM

Cylinder head should not be removed while hot as it may warp as a result. If cylinder head mounting surface is warped or pitted, up to 0.3 mm (0.012 inch) of material may be lapped from head to true surface.

Valve face angle is 45° for both valves. Renew valve if head margin is less than 0.5 mm (0.002 inch). Valve seat angle is 45° and recommmended seat width is 1.4-1.6 mm (0.055-0.065 inch). Renewable valve seat inserts are used on intake and exhaust. Before installing new inserts, cylinder head should first be heated to 160°-189°C (320°-355°F).

With valves installed, measure distance valve head is recessed from cylinder head surface. Intake valve should be recessed 0.70-0.90 mm (0.028-0.035 inch) and exhaust valve (except models with compression release) should be recessed 0.25-0.75 mm (0.010-0.030 inch). With compression release, exhaust valve recession should be 0.55-0.95 mm (0.022-0.037 inch). If recession is less than specified, regrind valve seat. If valve recession exceeds specified limit, renew valve seat insert.

Valve stem diameter is 6.98-7.00 mm (0.2748-0.2756 inch). Desired valve stem clearance in guide is 0.03-0.08 mm (0.001-0.003 inch) for both valves and maximum allowable clearance is 0.15 mm (0.006 inch). Valve guides are renewable and oversize guides are available. Outer diameter of oversize guide must be machined to provide a 0.05-0.06 mm (0.0020-0.0023 inch) interference fit in cylinder head bore. Cylinder head should be heated to 160°-180°C (320°-355°F) prior to installing new guides. A locating ring around top of guide determines distance guide is pressed into head. After installation, check guide inside diameter and ream as necessary to provide desired valve stem clearance.

Intake and exhaust valve springs are identical. Spring free length should be 42 mm (1.653 inches). Valve spring pressure should be 219-233 N (49-52 pounds) at 32 mm (1.260 inches).

The cylinder head gasket is available in varying thicknesses to adjust clearance between cylinder head surface and top of piston. Clearance must be 0.6-0.7 mm (0.024-0.027 inch) with piston at TDC. To determine required gasket thickness, measure from piston crown to gasket seating surface of cylinder as shown in Fig. L3-9. Subtract measurement (if piston is below sealing surface) or add measurement (if piston is above sealing surface) to 0.6-0.7 mm (0.024-0.027 inch) to obtain required gasket thickness. Gaskets are available

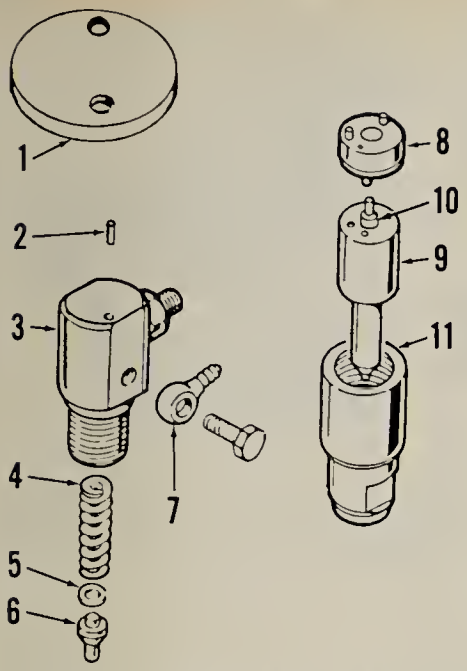


Fig. L3-11—Exploded view of injector.

1. Clamp plate
2. Dowel pin
3. Nozzle body
4. Spring
5. Shim
6. Spring seat
7. Return line fitting
8. Spacer
9. Nozzle tip
10. Valve
11. Nozzle holder nut

in thicknesses of 0.5 mm (0.020 inch), 0.6 mm (0.023 inch), 0.7 mm (0.027 inch) and 0.8 mm (0.031 inch).

Tighten cylinder head nuts in steps using a crossing pattern as shown in Fig. L3-10. Final torque should be 34 N·m (25 ft.-lbs.).

INJECTOR

REMOVE AND REINSTALL. To remove injector, first clean dirt from injector, injection line, return line and cylinder head. Disconnect fuel return line and injection line and immediately cap or plug all openings. Unscrew retainer plate nuts and lift off retainer plate (1 – Fig. L3-11) being careful not to lose dowel pin (2). Injector may now be carefully removed from cylinder head. Do not lose shims between injector and cylinder head.

Tighten injector retaining plate nuts to 12 N·m (9 ft.-lbs.). If accessible, measure protrusion of nozzle into combustion chamber. Nozzle tip should extend 2.5-3.0 mm (0.100-0.118 inch) above adjacent combustion chamber surface. Adjust position of nozzle by installing shims between injector and cylinder head. Shims are available in thicknesses of 0.5 mm (0.020 inch) and 1.0 mm (0.040 inch).

TESTING. A suitable test stand is required to check injector operation. Only clean, approved testing oil should be used to test injector.

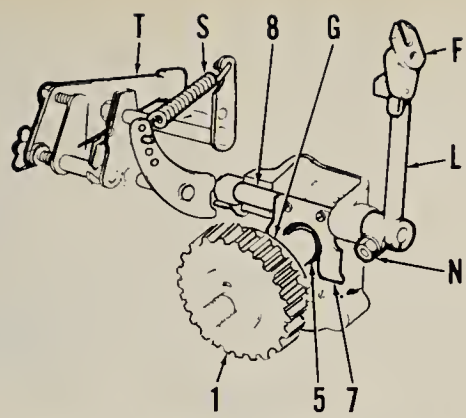


Fig. L3-12—View of governor mechanism. Refer to text for operation.

WARNING: Fuel leaves the injection nozzle with sufficient force to penetrate the skin. When testing, keep yourself clear of nozzle spray.

Connect injector to tester and operate tester lever to purge air from nozzle and to make sure nozzle valve is not stuck. When operating properly, injector nozzle will emit a buzzing sound and cut off quickly with no leakage at the tip.

Opening pressure should be 19610-21575 kPa (2845-3130 psi) on Models 500, 520 and 530. On all other models, opening pressure should be 18630-19610 kPa (2700-2845 psi). If a new spring (4 – Fig. L3-11) is being used, set opening pressure 1000 kPa (145 psi) higher than specified pressure settings to compensate for spring taking a set during initial operation. On all models, opening pressure is adjusted by varying thickness of shims (5).

To check for leakage past nozzle valve, operate tester lever slowly to maintain pressure at 2100 kPa (300 psi) below opening pressure. If a drop of fuel forms on nozzle tip within a 10 second period, nozzle valve must be overhauled or renewed. Slight wetness at the tip is permissible.

Operate tester lever briskly and check for an even and well atomized spray pattern. If pattern is wet, ragged or intermittent nozzle must be overhauled or renewed.

OVERHAUL. Clamp nozzle body (3 – Fig. L3-11) in a vise with nozzle tip pointing upward. Remove nozzle holder nut (11). Remove nozzle valve (9) and spacer (8). Invert nozzle body and remove spring seat (6), shims (5) and spring (4).

Thoroughly clean all parts in a suitable solvent. Do not use steel wire brush or sharp metal tools to clean injector components. Clean inside orifice end of nozzle valve with wooden cleaning stick. The orifice spray holes may be cleaned by inserting a cleaning wire slightly smaller in diameter than the spray holes. Spray hole diameter is 0.20 mm (0.008 inch) on Models 500, 520 and 530 or 0.24 mm (0.009 inch) on all other models. Make certain nozzle needle (10) slides freely in bore of nozzle valve set (9). If needle sticks, reclean or renew nozzle assembly.

When reassembling injector, be sure all components are clean and wet with diesel fuel. Recheck injector operation as outlined in TESTING paragraph.

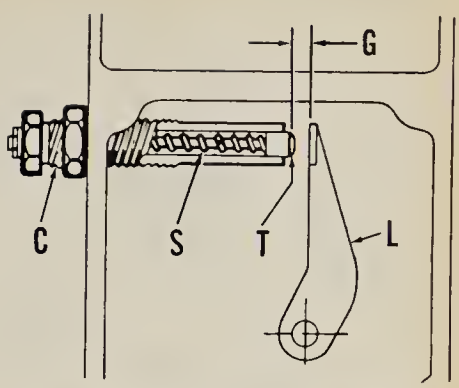


Fig. L3-13—View of torque control screw. Refer to text for adjustment.

INJECTION PUMP

Refer to Fig. L3-5 for an exploded view of injection pump. To remove pump, disconnect fuel lines and immediately plug all openings to prevent entry of dirt. Remove retaining screws and lift out pump assembly. Be sure to retain pump mounting gaskets for use in reassembly. Pump timing is adjusted by changing gasket thickness.

It is recommended that injection pump be tested and serviced only by a shop qualified in diesel fuel injection repair.

When reinstalling pump, assemble correct thickness of mounting shim gaskets and be sure to engage control rack pin with governor arm. Tighten pump mounting screws to a torque of 25 N·m (18 ft.-lbs.). Loosen clamp nut (N – Fig. L3-12), then move throttle lever (T) to full speed position. Push governor lever (L) in until it stops thus moving injection pump control sleeve to maximum delivery. Tighten clamp nut (N).

Torque control screw (C – Fig. L3-13) serves as the full-load stop for governor linkage (L). Control screw is equipped with a spring-loaded tip which allows additional fuel delivery under high torque load. To adjust torque control screw, run engine at high idle with no load. Turn screw so there is a gap (G) between tip (T) and lever (L) of 2.3-2.7 mm (0.090-0.106 inch) on Model 500, 1.3-1.5 mm (0.050-0.060 inch) on Model 520 or 2.1-2.3 mm (0.083-0.090 inch) on all other models.

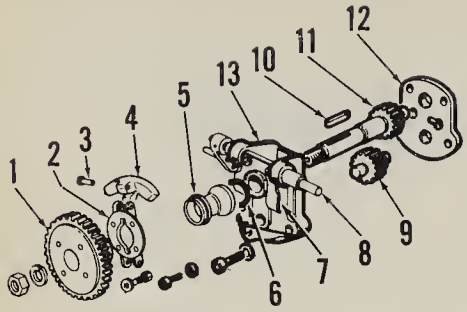


Fig. L3-14—Exploded view of governor and oil pump assembly.

1. Drive gear
2. Governor frame
3. Pins
4. Weights
5. Sleeve
6. Stop
7. Fork
8. Spindle
9. Gear
10. Key
11. Gear & shaft
12. Cover
13. Oil pump body

GOVERNOR

All models are equipped with a flyweight or ball type centrifugal governor which is attached to the back of oil pump drive gear as shown in Fig. L3-14. The oil pump drive gear (1) is driven by the crankshaft and rotates governor flyweights or balls. Movement of flyweights or balls causes sleeve (5) to move against fork (7) which rotates attached governor shaft (8). As governor shaft rotates, the governor lever (L-Fig. L3-12) forces arm (F) against a pin in the injection pump control sleeve thereby controlling fuel delivery to cylinder. Throttle lever (T) operates through governor spring (S) to control engine speed.

Governor components must move freely for proper governor operation. Governor spring (S – Fig. L3-12) free length should be 56.9-57.0 mm (2.240-2.244 inches). Spindle (8 – Fig. L3-14) diameter should be 7.95-7.96 mm (0.3130-0.3134 inch). Desired clearance between spindle and bore in oil pump housing (13) is 0.06-0.10 mm (0.002-0.004 inch) with a maximum allowable clearance of 0.15 mm (0.006 inch).

OIL PUMP

Refer to Fig. L3-14 for an exploded view of oil pump. The oil pump is accessible for removing crankcase cover (3 – Fig. L3-15). Clearance between gears and pump body walls must not exceed 0.15 mm (0.006 inch). Renew oil pump if components are excessively worn or damaged. Tighten pump mounting screws evenly to 12 N·m (9 ft.-lbs.).

CAMSHAFT, CAM FOLLOWERS AND PUSH RODS

The camshaft rides directly in crankcase cover and crankcase bulkhead and is accessible after removing crankcase cover (3 – Fig. L3-15). Cam followers (7 and 8) pivot on stud (9) and transfer motion to push rods (26) which pass through tube (28) to rocker arms. In addition to valve actuating lobes, a lobe is ground on the camshaft to operate the fuel injection pump. On Models 6LD260/C, 6LD325/C and 6LD360/C, the camshaft also serves as the power takeoff.

Camshaft bearing journal diameters are 19.937-19.970 mm (0.7849-0.7862 inch) and 25.937-25.950 mm (1.0211-1.0216 inches). If wear exceeds 0.10 mm (0.004 inch), renew camshaft.

Cam follower pivot stud (9) diameter should be 9.4-9.6 mm (0.370-0.378 inch). Maximum allowable clearance between pivot stud and cam followers is 0.10 mm (0.004 inch).

Install camshaft so timing marks (M – Fig. L3-16) are aligned. If timing marks are absent from gears, proceed as follows: Position piston at top dead center (TDC) then install camshaft so intake cam follower is on opening side of cam lobe and exhaust cam follower is on closing side of cam lobe. If necessary, remesh gears so cam followers are at same height. Mark gears for future reference.

Depth of camshaft in crankcase must not be greater than 0.10 mm (0.004 inch) as measured from thrust face (TF – Fig. L3-16) to crankcase gasket surface (G). Camshaft end play should be 0.10-0.30 mm (0.004-0.012 inch) and is adjusted by varying thickness of crankcase cover gasket (4 – Fig. L3-15). Apply Loctite to crankcase cover (3) screws and tighten to 45 N·m (33 ft.-lbs.).

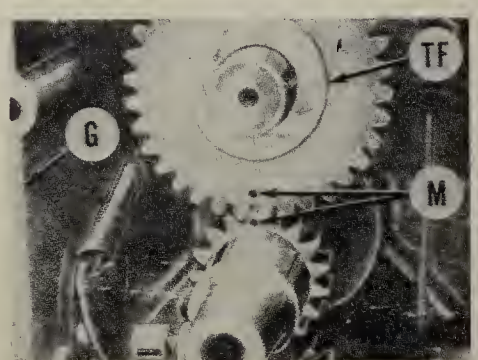


Fig. L3-16—View of camshaft and crankshaft gear timing marks (M). Measure depth of camshaft thrust face (TF) from crankcase gasket surface (G) as outlined in text.

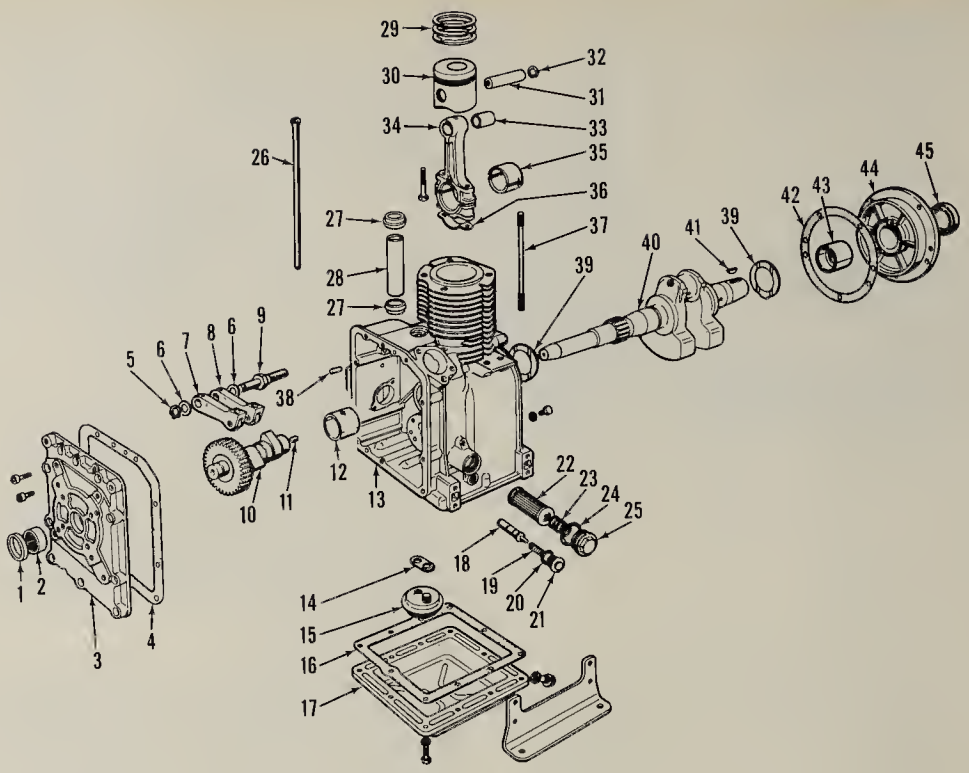


Fig. L3-15—Exploded view of engine.

1. Seal
2. Roller bearing
3. Crankcase cover
4. Gasket
5. Snap ring
6. Washer
7. Exhaust cam follower
8. Intake cam follower
9. Stud
10. Camshaft
11. Plug
12. Bushing
13. Engine block
14. Gasket
15. Oil pickup
16. Gasket
17. Oil pan
18. Oil pressure relief valve
19. Spring
20. Gasket
21. Plug
22. Oil filter
23. Spring
24. "O" ring
25. Plug
26. Push rods
27. Seal
28. Push rod tube
29. Piston rings
30. Piston
31. Piston pin
32. Snap ring
33. Bushing
34. Connecting rod
35. Rod bearing
36. Lockplate
37. Studs
38. Dowel pins
39. Thrust washers
40. Crankshaft
41. Key
42. Gasket
43. Bushing
44. Support
45. Seal

Fig. L3-17—Install piston so depression (D) is nearer flywheel side of engine. Some pistons may have an arrow on crown and arrow must point towards flywheel.

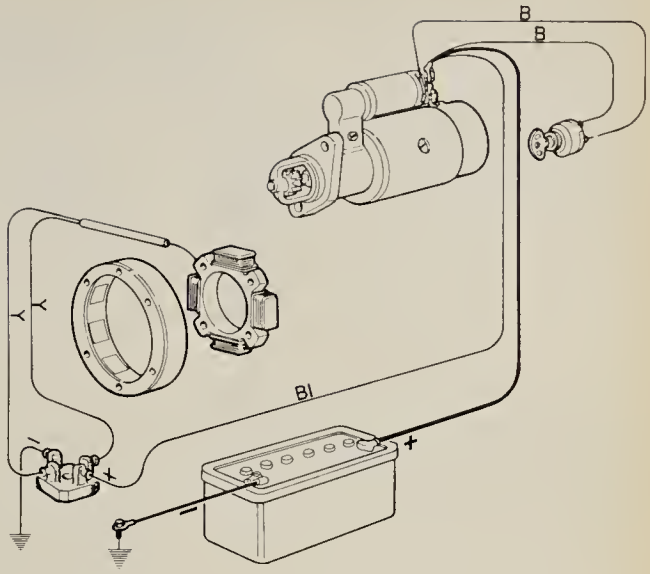


Fig. L3-18—Typical wiring schematic for engines equipped with alternator and electric starter.

The push rods are contained in tube (28) and must cross between cam followers and rocker arms. Push rod nearer cylinder connects intake cam follower and rocker arm while outer push rod connects exhaust cam follower and rocker arm.

PISTON AND ROD UNIT

Piston and connecting rod may be removed after removing cylinder head and oil pan.

When reinstalling piston and rod, note that depression (D – Fig. L3-17) in piston crown is closer to one side of piston. Install piston so depression side of piston is aligned with injector. Some pistons also have an arrow embossed in piston crown as shown in Fig. L3-17. Properly installed, arrow on piston crown will point towards flywheel.

The connecting rod and cap have machined serrations which must mate during assembly. Match marks on rod and cap must be on same side. Tighten connecting rod screws to 34 N·m (25 ft.-lbs.).

PISTON, PIN, RINGS AND CYLINDER

The piston on early models (before engine number 1098888) is equipped with two compression rings and one oil control ring. Late model engines are equipped with three compression rings and one oil control ring.

On Models 500, 520 and 530, ring end gap should be 0.25-0.40 mm (0.010-0.015 inch) for all compression rings and 0.20-0.35 mm (0.008-0.013 inch) for the oil ring. On all other models, ring end gap should be 0.25-0.45 mm (0.010-0.018 inch) for top compression ring, 0.30-0.45 mm (0.012-0.018 inch) for second and third compression rings and 0.25-0.40 mm (0.010-0.015 inch) for oil ring. Be sure rings are positioned squarely in cylinder when checking end gap.

To check piston ring groove wear, install rings onto piston and measure side clearance between top of ring and top of groove. Side clearance should be 0.11-0.15 mm (0.005-0.006 inch) for top groove, 0.06-0.10 mm (0.002-0.004) inch for second and third compression ring grooves and 0.05-0.10 mm (0.002-0.004 inch) for oil ring groove. Renew piston if side clearance is excessive.

Clearance between piston pin and connecting rod bushing should be 0.01-0.03 mm (0.0004-0.0012 inch). If clearance exceeds 0.07 mm (0.0027 inch), renew pin and bushing. Pin should be a thumb push fit in piston.

Standard piston diameter, measured at bottom of skirt perpendicular to pin bore, is 69.90-69.93 mm (2.7519-2.7531 inches) for Models 6LD260, 500 and 6LD260/C; 77.89-77.92 mm (3.0665-3.0677 inches) on Models 6LD325, 520 and 6LD325/C; 81.88-81.89 mm (3.2236-3.2240 inches) on Models 6LD360, 530, 6LD360/C and 6LD360/V; 85.91-85.93 mm (3.3823-3.3830 inches) on Model 6LD400. Renew piston if skirt wear exceeds 0.05 mm (0.002 inch). Piston and rings are available in standard size and oversizes of 0.5 mm (0.020 inch) and 1.0 mm (0.040 inch).

Cylinder standard inside diameter is 70.00-70.02 mm (2.7559-2.7567 inches) on Models 6LD260, 500 and 6LD260/C; 78.00-78.02 mm (3.0708-3.0716 inches) on Models 6LD325, 520 and 6LD325/C; 82.00-82.02 mm (3.2283-3.2291 inches) on Models 6LD360, 530, 6LD360/C and 6LD350/V; 86.00-86.02 mm (3.3858-3.3866 inches) on Model 6LD400. If cylinder taper or out-of-round exceeds 0.1 mm (0.004 inch), rebore cylinder to appropriate oversize.

When reistalling rings onto piston, stagger ring end gaps 180° apart. Be sure no end gaps are in line with piston pin bore. Lubricate piston, rings and cylinder with clean engine oil prior to reassembly.

CONNECTING ROD

The connecting rod small end is fitted with a renewable bushing. Clearance between piston pin and bushing should be 0.01-0.03 mm (0.0004-0.0012 inch). An insert type bearing is used in connecting rod big end. Crankshaft crankpin diameter should be 39.99-40.00 mm (1.5744-1.5748 inches) and desired clearance in bearing is 0.03-0.06 mm (0.0012-0.0024 inch). Maximum allowable clearance is 0.10 mm (0.004 inch). Bearings are available in undersizes of 0.25 mm (0.010 inch) and 0.50 mm (0.020 inch) as well as standard size.

CRANKSHAFT AND CRANKCASE

The crankshaft is supported by bushing (12 – Fig. L3-15) in the crankcase bulkhead, bushing (43) in support (44) on flywheel side and by a roller bearing (2) in the crankcase cover (3).

Desired bearing clearance for center and flywheel end main bearings is 0.03-0.06 mm (0.0012-0.0024 inch). Crankshaft journal diameter for center and flywheel end bearings is 39.99-40.00 mm (1.5744-1.5748 inches). Special bearing installing tool 7271.3595.047 is available from Lombardini to properly

install main bearings. Be sure oil hole in center bearing is aligned with hole in crankcase.

Crankshaft end thrust is taken by thrust washers (39–Fig. L3-15). Thrust washer thickness should be 2.31-2.36 mm (0.090-0.092 inch). Desired crankshaft end play is 0.10-0.30 mm (0.004-0.012 inch). End play is adjusted by removing or adding gaskets (42) between support (44) and crankcase.

Inspect oil seals (1 and 45) and renew if necessary. Be sure to lubricate lip of seals before reassembling. Tighten flywheel side support plate cap screws to a torque of 30 N·m (22 ft.-lbs.) and crankcase cover cap screws to 45 N·m (33 ft.-lbs.).

ALTERNATOR

The internal alternator is mounted on the flywheel end of engine. The stator is secured to the engine crankcase while a ring of permanent magnets is carried by the flywheel. Note wiring schematic in Fig. L3-18.

LOMBARDINI

Model	No. Cyls.	Bore	Stroke	Displ.
7LD600/I, 710	1	90 mm (3.543 in.)	94 mm (3.700 in.)	598 cc (36.5 cu. in.)
7LD665/I, 720	1	95 mm (3.740 in.)	94 mm (3.700 in.)	666 cc (40.6 cu. in.)
7LD740/I	1	100 mm (3.937 in.)	94 mm (3.700 in.)	738 cc (45.0 cu. in.)

All models are four-stroke, air-cooled diesel engines. The crankcase and cylinder head are aluminum and cylinder barrel is cast iron. Crankshaft rotation is counterclockwise at pto end.

MAINTENANCE

LUBRICATION

Recommended engine oil is SAE 10W for temperatures below 0°C (32°F), SAE 20W for temperatures between 0°C (32°F) and 20°C (68°F), and SAE 40 for temperatures above 20°C (68°F). API classification for oil should be CD. Oil sump capacity is 2.2 liters (2.3 quarts). Manufacturer recommends renewing oil after every 300 hours of operation.

A renewable oil filter is located inside the engine block and can be renewed after removing cover plate (O–Fig. L4-1). Manufacturer recommends renewing filter after every 300 hours of operation.

All models are equipped with a pressurized oil system. Refer to Fig. L4-2 for a diagram of the oil circuit.

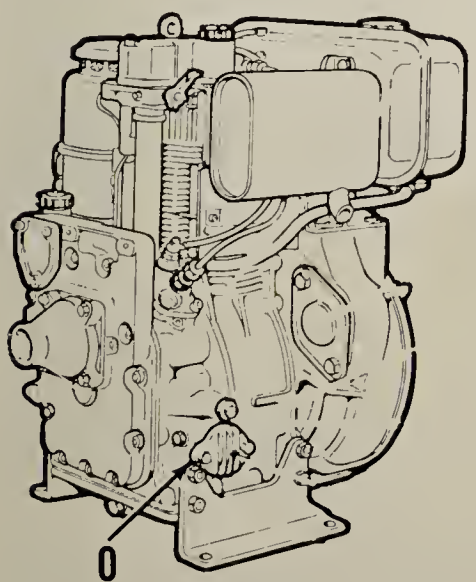


Fig. L4-1—Remove plate (O) for access to oil filter.

ENGINE SPEED ADJUSTMENT

Idle speed is adjusted by turning idle speed screw (I–Fig. L4-3). Idle speed should be 1000-1100 rpm. Maximum governed speed is adjusted by turning high speed screw (H). Adjust high idle (no-load) speed 180 rpm above specified rated full-load speed to compensate for governor droop during operation. Maximum full-load speed is normally 3000 rpm, but speed may vary depending upon application.

FUEL SYSTEM

FUEL FILTER. The fuel filter is located inside the fuel tank as shown in Fig. L4-4. Renew fuel filter after every 300 hours of operation or sooner if required.

BLEED FUEL SYSTEM. To bleed fuel system, loosen fuel line fitting on injection pump and allow fuel to flow until air-free, then retighten fitting. Loosen high pressure injection line at injector,

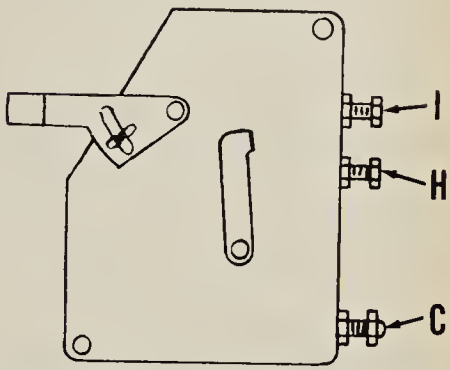


Fig. L4-3—View of speed adjusting screws: (I) Low idle speed; (H) High idle speed; (C) Torque control. Refer to text for adjustment.

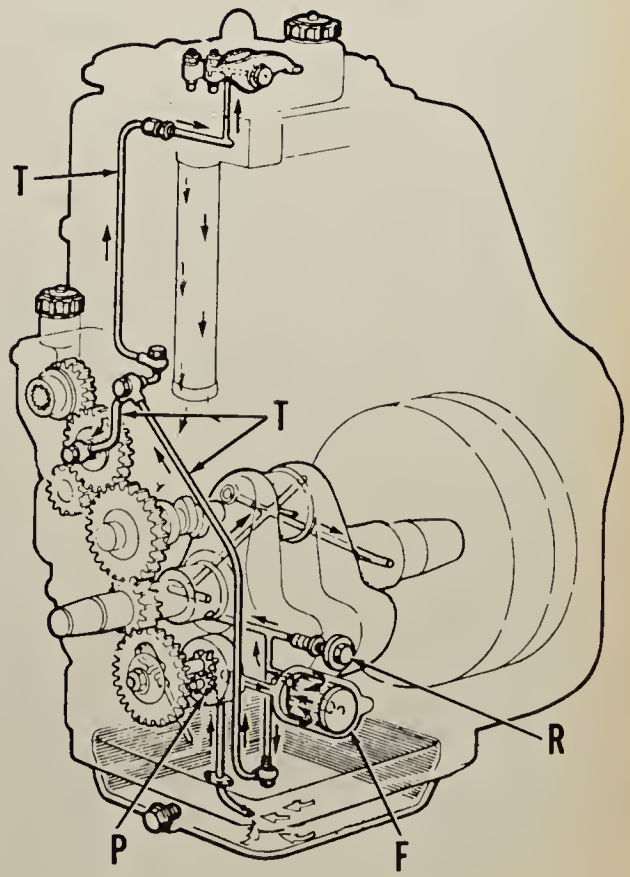


Fig. L4-2—Diagram of engine oil lubrication circuit. Note oil tubes (T) which route oil to engine top end.
F. Oil filter
P. Oil pump
R. Oil relief valve
T. Oil tubes

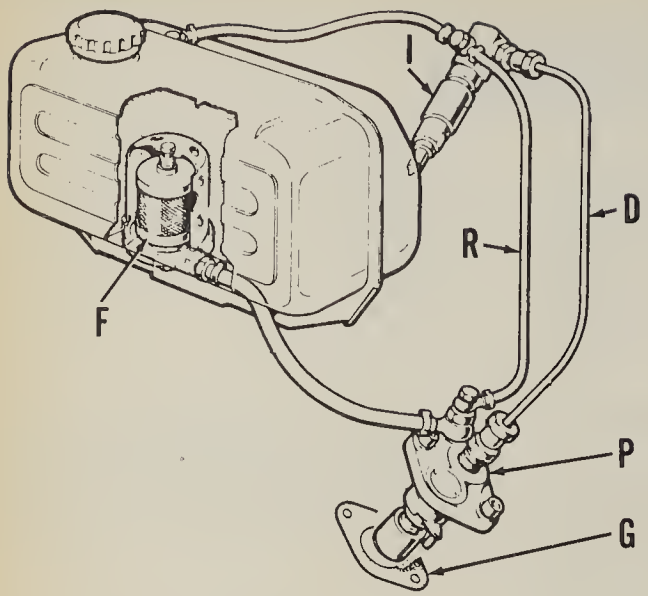


Fig. L4-4—Diagram of fuel circuit.

D. High pressure line
F. Fuel filter
G. Shim gasket
I. Injector
P. Injection pump
R. Return line

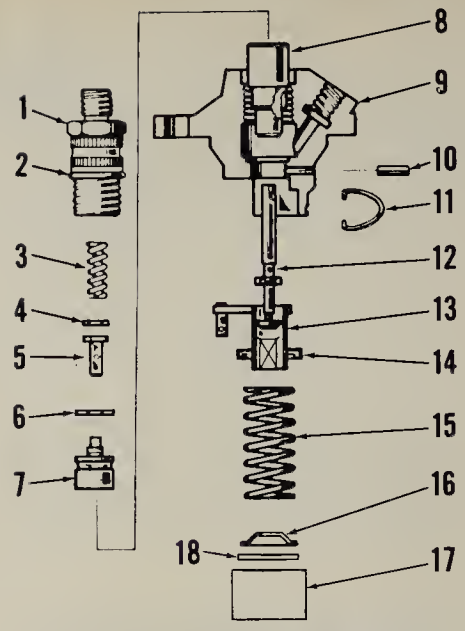


Fig. L4-5—View of fuel injection pump.

1. Delivery valve holder
2. "O" ring
3. Spring
4. Washer
5. Delivery valve
6. Gasket
7. Delivery valve seat
8. Barrel
9. Pump body
10. Pin
11. Clip
12. Plunger
13. Control sleeve
14. Spring seat
15. Spring
16. Spring retainer
17. Tappet
18. Spacer

then rotate engine crankshaft to operate injection pump until air-free fuel flows from injection line. Retighten injection line.

INJECTION PUMP TIMING

Injection pump timing is adjusted by changing thickness of shim gaskets (G–Fig. L4-4) between injection pump body and crankcase mounting surface. To check injection pump timing, disconnect high pressure delivery line from pump and remove delivery valve holder (1–Fig. L4-5). Remove spring (3), washer (4) and delivery valve (5). Do not remove valve seat (7). Reinstall delivery valve holder. Move throttle control to full speed position. Rotate crankshaft in normal direction so piston is on compression stroke. Note that fuel should spill out of delivery valve holder during this operation. Continue to rotate crankshaft until fuel stops flowing from delivery valve holder. Stop crankshaft rotation at moment fuel ceases to flow out. At this point, beginning of injection occurs and timing dot (R–Fig. L4-6) on fan plate should align with timing dot (I) on fan shroud.

Injection timing is 23°-25°BTDC on Models 710 and 720, 26°-28° BTDC on Model 7LD740 and 24°-26° BTDC on all other models. To advance injection timing, remove pump and reduce thickness of shim gaskets (G–Fig. L4-4). To retard injection timing, add pump shim gaskets. Reinstall delivery valve components after checking timing. Tighten delivery valve holder to a torque of 34 N·m (25 ft.-lbs.). Tighten injection pump retaining screws to 25 N·m (18 ft.-lbs.). Bleed air from fuel system as outlined in previous paragraph.

REPAIRS

TIGHTENING TORQUES

Refer to the following table for tightening torques.

Connecting rod	49 N·m (36 ft.-lbs.)
Crankcase cover	25 N·m (18 ft.-lbs.)
Cylinder head	60 N·m (44 ft.-lbs.)
Flywheel	295 N·m (217 ft.-lbs.)
Idler gear	20 N·m (15 ft.-lbs.)
Injection pump	25 N·m (18 ft.-lbs.)
Injector retainer plate	10 N·m (7 ft.-lbs.)
Main bearing support	30 N·m (22 ft.-lbs.)
Oil pan	25 N·m (18 ft.-lbs.)
Oil pump	10 N·m (7 ft.-lbs.)
Oil pump gear	49 N·m (36 ft.-lbs.)
Rocker arm cover	20 N·m (15 ft.-lbs.)
Rocker arm shaft	25 N·m (18 ft.-lbs.)

VALVE CLEARANCE ADJUSTMENT

To adjust valve clearance, first remove rocker arm cover. Rotate crankshaft until piston is at TDC on compression stroke. Clearance between valve stem end and rocker arm should be 0.10-0.15 mm (0.004-0.006 inch) for both intake and exhaust with engine cold.

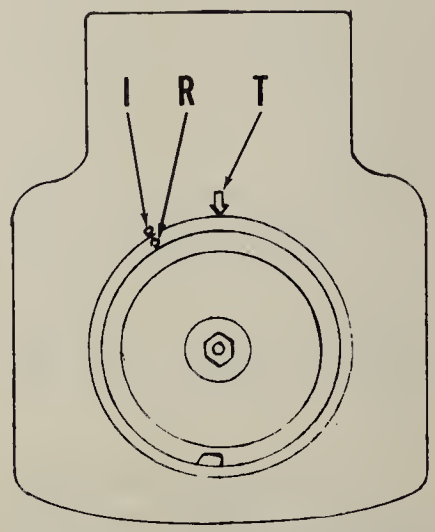


Fig. L4-6—Injection should occur when timing dot (R) on fan plate is aligned with injection timing dot (I) on fan shroud. Piston is at TDC when timing dot (R) and arrow (T) are aligned.

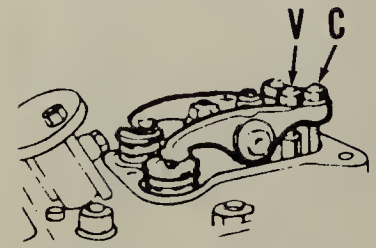


Fig. L4-7—Adjust exhaust valve clearance by turning adjustment screw (V). Adjust compression release by turning adjustment screw (C). Refer to text.

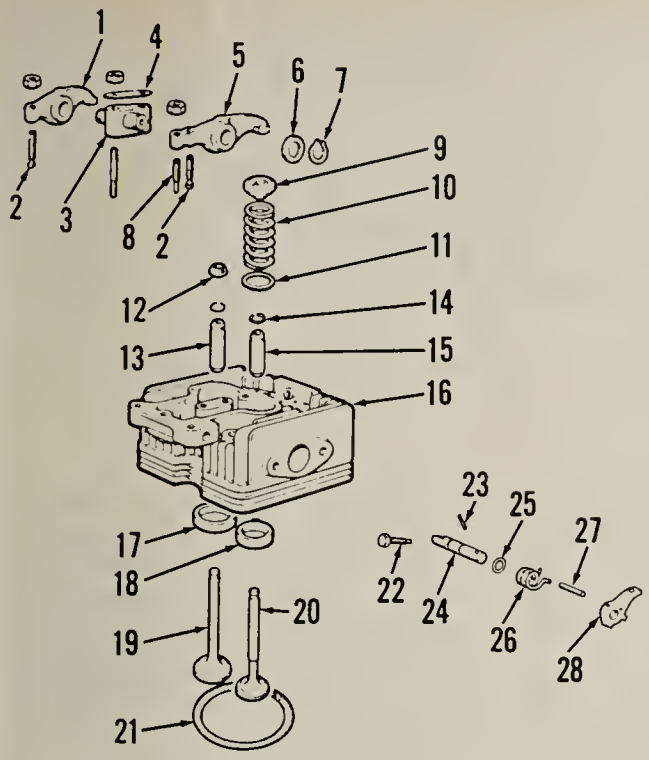


Fig. L4-8—Exploded view of cylinder head.

1. Intake rocker arm
2. Valve adjusting screws
3. Rocker stand
4. Plate
5. Exhaust rocker arm
6. Washer
7. Snap ring
8. Compression release adjusting screw
9. Spring retainer
10. Valve spring
11. Washer
12. Valve seal
13. Intake valve guide
14. Snap ring
15. Exhaust valve guide
16. Cylinder head
17. Intake valve seat
18. Exhaust valve seat
19. Intake valve
20. Exhaust valve
21. Head gasket
22. Locating screw
23. Pin
24. Compression release shaft
25. Washer
26. Spring
27. Pin
28. Compression release lever

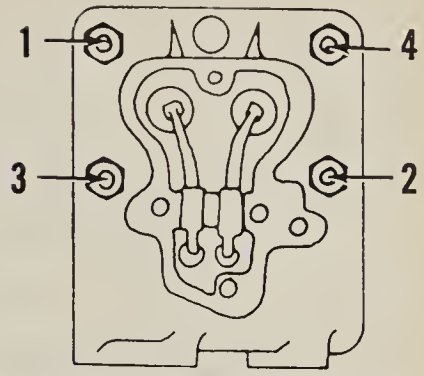


Fig. L4-9—Tighten cylinder head nuts in steps using a crossing pattern as shown. Final torque should be 60 N·m (44 ft.-lbs.).

Note that there are two adjusting screws (Fig. L4-7) in exhaust rocker arm. Adjusting screw (V) nearer rocker arm shaft is used to adjust valve clearance while outer screw (C) adjusts compression release gap.

COMPRESSION RELEASE

A manual compression release is located in the cylinder head so the exhaust valve can be held open to aid starting. Rotating shaft (24–Fig. L4-8) forces the exhaust rocker arm to slightly open the exhaust valve.

The compression release is adjusted by turning outer adjusting screw (C–Fig. L4-7) in exhaust valve rocker arm. Adjust compression release gap AFTER adjusting exhaust valve clearance. With compression release lever in disengaged position, clearance between adjusting screw and shaft should be 0.9-1.1 mm (0.035-0.043 inch).

Diameter of compression release shaft (24–Fig. L4-8) is 9.37-10.00 mm (0.369-0.393 inch) while lobe height is 8.45-8.50 mm (0.333-0.334 inch).

CYLINDER HEAD AND VALVE SYSTEM

Cylinder head should not be removed when hot as head may deform. If cylinder head mounting surface is warped or pitted, up to 0.3 mm (0.012 inch) of material may be lapped from head to true surface.

Valve face angle is 45° for both valves. Renew valve if head margin is less than 0.4 mm (0.016 inch). Valve seat angle is 45° and recommended seat width is 1.4-1.6 mm (0.055-0.065 inch). Renewable valve seat inserts are used on intake and exhaust. Before installing new inserts, cylinder head should first be heated in an oven to 160°-180°C (320°-355°F).

With valves installed, measure distance valve head is recessed from cylinder head surface. Intake valve should be recessed 0.60-0.80 mm (0.024-0.031 inch) and exhaust valve (without compression release) should be 0.075-1.25 mm (0.030-0.049 inch). With compression release, exhaust valve recession should be 0.55-0.95 mm (0.022-0.037 inch). If recession is less than specified, regrind valve seat. If valve recession exceeds specified limit, renew valve seat insert.

Valve stem diameter is 7.98-8.00 mm (0.3142-0.3149 inch). Desired valve stem clearance in guide is 0.03-0.08 mm (0.001-0.003 inch) and maximum allowable clearance is 0.15 mm (0.006 inch). Valve guides are renewable and oversize guides are available. Outer diameter of oversize guide must be machined to provide a 0.05-0.06 mm (0.0020-0.0023 inch) interference fit in cylinder head bore. Cylinder head should be heated to 160°-180°C (320°-355°F) prior to installing new guides. A locating ring (14–Fig. L4-8) around top of guide determines distance guide is pressed into head. After installation, check guide inside diameter and ream as necessary to provide desired valve stem clearance.

Intake and exhaust valve springs are identical. Spring free length should be 52 mm (2.047 inches). Valve spring pressure should be 304-323 N (68-72 pounds) when compressed to a length of 25.8 mm (1.015 inches).

Desired clearance between rocker arms and shaft is 0.03-0.06 mm (0.001-0.002 inch). Maximum allowable clearance is 0.1 mm (0.004 inch). Tighten rocker arm shaft retaining screws to a torque of 25 N·m (18 ft.-lbs.).

Tighten cylinder head nuts gradually in steps using a crossing pattern as shown in Fig. L4-9. Final torque should be 60 N·m (44 ft.-lbs.).

INJECTOR

REMOVE AND REINSTALL. To remove injector, first clean dirt from injector, injection line, return line and cylinder head. Disconnect fuel return

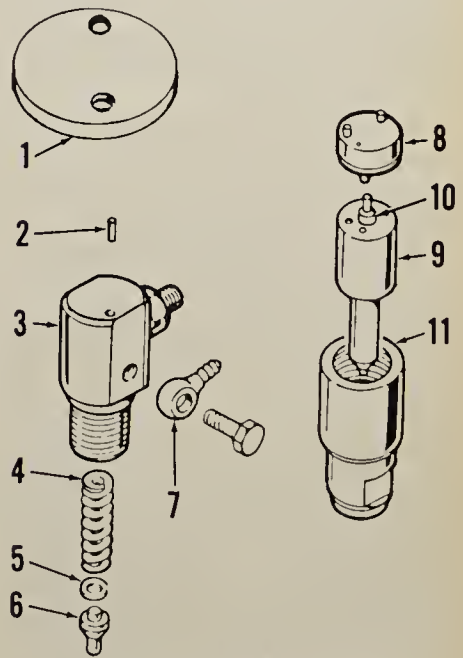


Fig. L4-10—Exploded view of Injector.

1. Clamp plate
2. Dowel pin
3. Nozzle body
4. Spring
5. Shim
6. Pressure pin
7. Return line fitting
8. Spacer
9. Nozzle
10. Valve
11. Nozzle holder nut

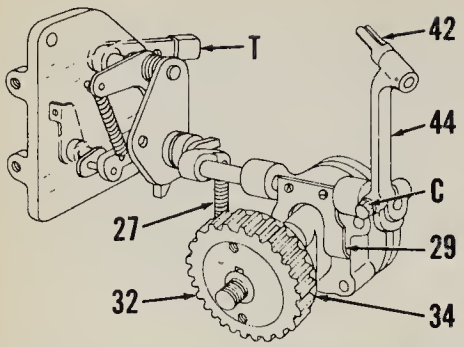


Fig. L4-11—Diegrem of governor assembly. Refer to text for operetion and adjustment.

C. Clamp screw
T. Throttle lever
27. Spring
29. Fork
32. Oil pump drive gear
34. Flyball assy.
42. Arm
44. Governor lever

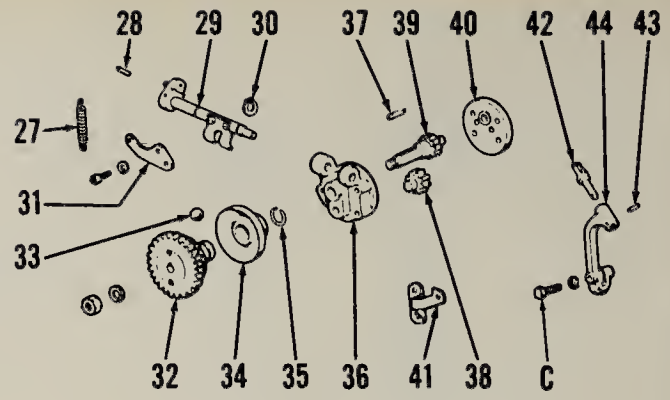


Fig. L4-12—Exploded view of governor and oil pump.

27. Governor spring
28. Pin
29. Shaft & fork
30. Snap ring
31. Spring plate
32. Oil pump drive gear
33. Governor balls (3)
34. Flyball housing
35. Snap ring
36. Oil pump body
37. Key
38. Driven gear
39. Drive gear & shaft
40. Oil pump plate
41. Bracket
42. Governor arm
43. Pin
44. Governor lever

line and injection line and immediately cap or plug all openings. Unscrew retainer plate (1 – Fig. L4-10) being careful not to lose dowel pin (2). Injector may now be carefully removed from cylinder head. Do not lose shims between injector and cylinder head.

Tighten injector retaining plate nuts to 10 N·m (7 ft.-lbs.). If accessible, measure protrusion of nozzle into combustion chamber. Nozzle tip should extend 3.5-4.0 m (0.138-0.157 inch) above adjacent combustion chamber surface. Adjust position of nozzle by installing 0.5 mm (0.020 inch) shims between injector and cylinder head.

TESTING. A suitable test stand is required to check injector operation. Only clean, approved testing oil should be used to test injector.

WARNING: Fuel leaves the injection nozzle with sufficient force to penetrate the skin. When testing, keep yourself clear of nozzle spray.

Connect injector to tester and operate test lever to purge air from nozzle and make sure nozzle valve is not stuck. When operating properly, injector nozzle will emit a buzzing sound and cut off quickly with no leakage at the tip.

Opening pressure should be 20595-21575 kPa (2985-3130 psi). Opening pressure is adjusted by varying number and thickness of shims (5 – Fig. L4-10). Operate tester lever slowly to maintain pressure at 2100 kPa (300 psi) below opening pressure and check for leakage past nozzle tip. If a drop appears within a 10 second period, nozzle valve must be overhauled or renewed. A slight wetness at tip is permissible. Operate tester lever briskly and check for even and well atomized spray pattern. If pattern is wet, ragged or intermittent, nozzle must be overhauled or renewed.

OVERHAUL. To disassemble nozzle, secure nozzle body (3 – Fig. L4-10) in a vise with nozzle tip pointing upward. Remove nozzle holder nut (11) and withdraw nozzle valve (9 and 10) and spacer (8). Invert nozzle body (3) and remove spring seat (6), shim (5) and spring (4).

Thoroughly clean all parts in a suitable solvent. Do not use steel wire brush or sharp metal tools to clean injector components. Clean inside the orifice end of nozzle valve with a wooden cleaning stick. The orifice spray holes may be cleaned by inserting a cleaning wire slightly smaller in diameter than the spray hole diameter of 0.28 mm (0.011 inch). Make certain nozzle needle (10) slides freely in bore of nozzle valve seat (9). If needle sticks, reclean or renew nozzle valve assembly.

When reassembling injector, be sure all parts are clean and wet with diesel fuel. Recheck injector operation outlined in TESTING paragraph.

INJECTION PUMP

Refer to Fig. L4-5 for an exploded view of injection pump. To remove pump, dis connect fuel lines and immediately plug all openings to prevent entry of dirt. Remove retaining screws and lift out pump assembly. Be sure to retain pump mounting shim gaskets for use in reassembly. Pump timing is adjusted by changing gasket thickness.

It is recommended that injection pump be tested and serviced only by a shop qualified in diesel fuel injection repair.

When reinstalling pump, assemble correct thickness of mounting shim gaskets and be sure to engage control rack pin with governor arm. Tighten pump mounting screws to a torque of 25 N·m (18 ft.-lbs.). If pump was overhauled or renewed, check and adjust injection timing as outlined in MAINTENANCE section.

To adjust control linkage, first move throttle lever (T – Fig. L4-11) to full speed position. Loosen clamp screw (C) and push governor lever (44) in until it stops thus moving injection pump control sleeve to maximum delivery. Retighten clamp screw (C).

GOVERNOR

All models are equipped with a flyball centrifugal type governor which is attached to the back of the oil pump drive gear (32 – Fig. L4-11 and L4-12). The oil pump drive gear (32) is driven by the crankshaft and rotates governor flyball assembly (34). Flyball housing (34) is interlocked with fork (29). As the flyballs move, the shaft attached to fork (29) is rotated thereby moving governor lever (44) and arm (42). Arm (42) mates with the pin on the injection pump control sleeve (13 – Fig. L4-5) to regulate fuel flow to cylinder. Throttle lever (T – Fig. L4-11) operates through governor spring (27) to control engine speed.

Torque control screw (C – Fig. L4-13 and L4-14) allows additional fuel usage under high torque load. The screw tip (T-Fig.

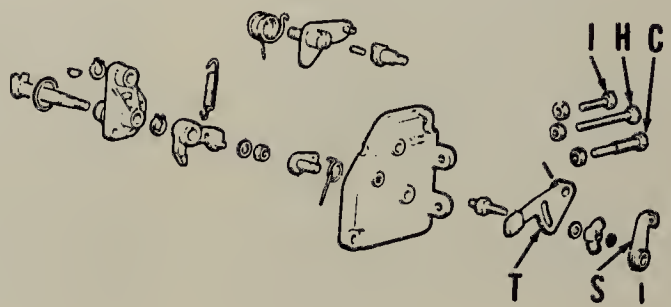


Fig. L4-13—Exploded view of throttle mechanism.

C. Torque control
H. High speed screw
I. Idle speed screw
S. Stop lever
T. Throttle lever

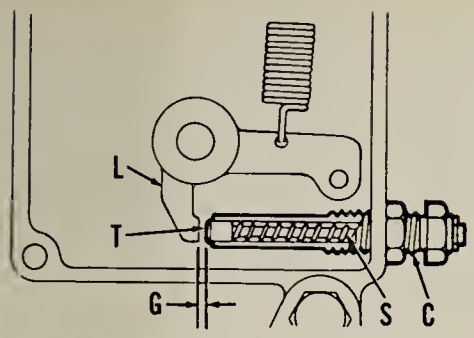


Fig. L4-14—Diagram of torque control screw. Refer to text for adjustment.

L4-14) is backed by spring (S). To adjust torque control screw, run engine at high idle with no load and turn screw so gap (G) between tip (T) and lever (L) is 2.1 mm (0.083 inch) on Models 710 and 7LD600 or 2.3 mm (0.090 inch) on Models 720 and 7LD655.

Inspect governor components and renew any which are damaged or excessively worn. Mechanism must move freely for proper governor operation.

OIL PUMP

R&R AND OVERHAUL. The oil pump is mounted on the crankcase bulkhead and is accessible after removing crankcase cover. Refer to Fig. L4-12 for an exploded view of oil pump.

Clearance between gears and body walls must not exceeed 0.15 mm (0.006 inch). Be sure pump shaft turns freely and axial end play does not exceed 0.15 mm (0.006 inch). Tighten pump mounting cap screws to a torque of 10 N·m (7 ft.-lbs.) and pump drive gear retaining nut to 49 N·m (37 ft.-lbs.).

CAMSHAFT, CAM FOLLOWERS AND PUSH RODS

R&R AND OVERHAUL. The camshaft rides in the crankcase bulkhead and crankcase cover (2–Fig. L4-15) and is accessible after removing cover. Cam followers (10 and 12) pivot on shaft (9) and transfer motion to push rods (56–Fig. L4-16) which pass through tube (57) to rocker arms. A lobe is ground on the camshaft to actuate the fuel injection pump.

On Models 710 and 720, intake and exhaust lobe height should be 29.36-29.56 mm (1.156-1.164 inches) and injection pump lobe height should be 42.6-42.8 mm (1.677-1.685 inches). On all other models, intake and exhaust lobe height should be 29.465-29.565 mm (1.160-1.164 inches) and injection pump lobe height should be 43.40-43.50 mm (1.708-1.712 inches). Bearing journal diameter should be 19.98-20.00 mm (0.7866-0.7874 inch) for both journals on all models.

Cam follower pivot shaft (9–Fig. L4-15) diameter should be 14.97-15.00 mm (0.589-0.590 inch). Maximum allowable clearance between shaft and cam followers is 0.10 mm (0.004 inch).

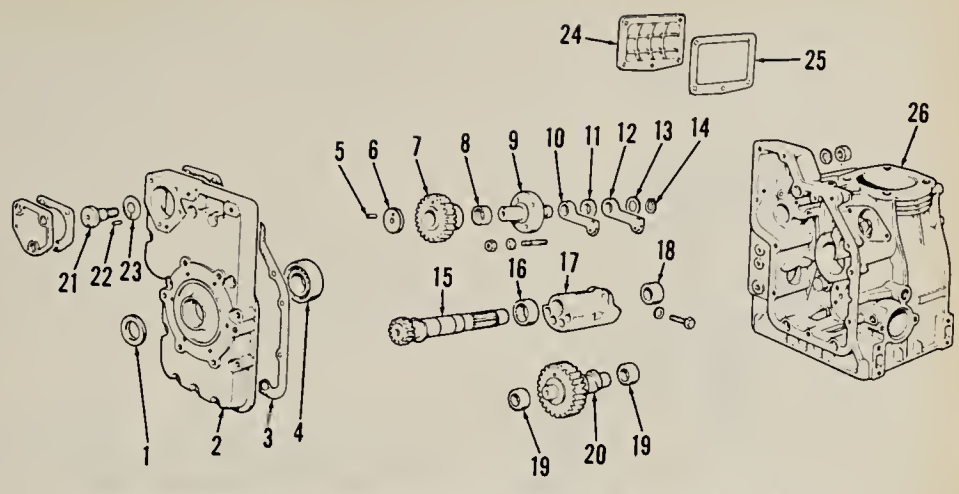


Fig. L4-15—Exploded view of camshaft, balancer and cam follower assemblies.

1. Seal
2. Crankcase cover
3. Gasket
4. Bearing
5. Pin
6. Washer
7. Idler gear
8. Bushing
9. Pivot shaft
10. Exhaust cam follower
11. Spacer
12. Intake cam follower
13. Washer
14. Snap ring
15. Balancer shaft
16. Bearing
17. Balancer
18. Bearing
19. Bearing
20. Camshaft
21. Stud
22. Pin
23. Washer
24. Side cover
25. Gasket
26. Crankcase

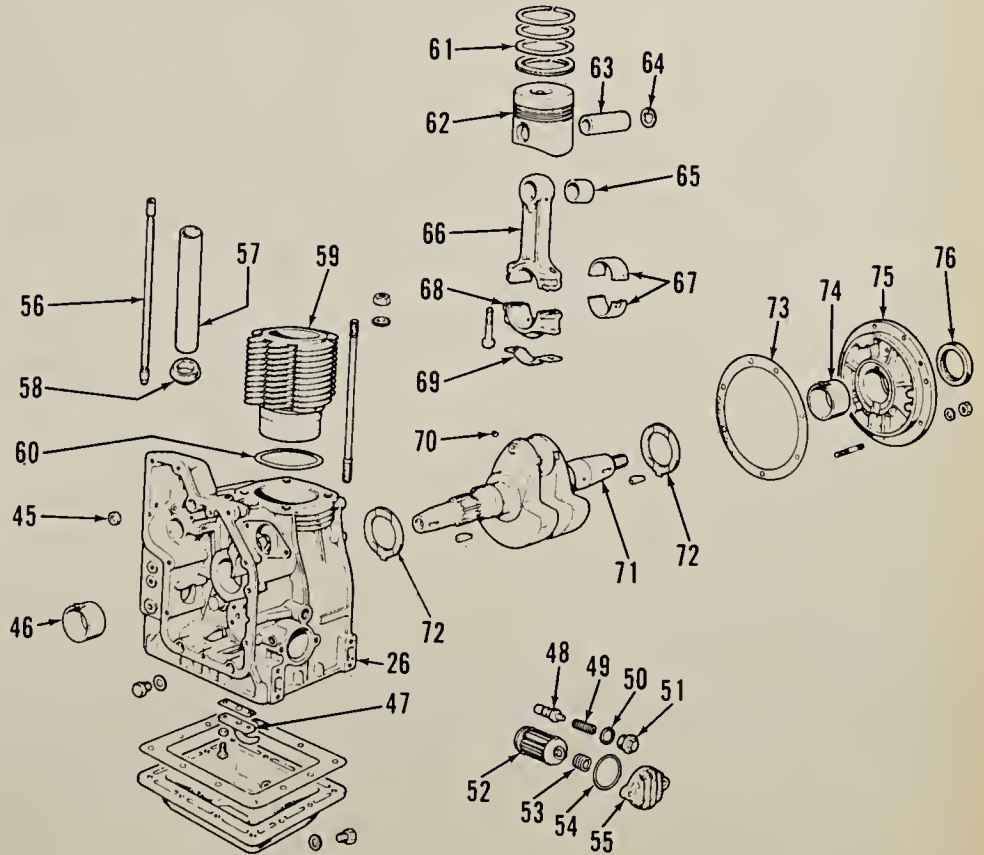


Fig. L4-16—Exploded view of crankshaft, piston and rod assemblies.

26. Crankcase
45. Hollow dowel (3)
46. Main bearing
47. Oil pickup
48. Oil pressure relief valve
49. Spring
50. Washer
51. Plug
52. Oil filter
53. Spring
54. Gasket
55. Plate
56. Push rods
57. Push rod tube
58. Grommets (2)
59. Cylinder
60. Gasket
61. Piston rings
62. Piston
63. Piston pin
64. Snap rings
65. Bushing
66. Connecting rod
67. Bearing
68. Rod cap
69. Lockplate
70. Expansion plug
71. Crankshaft
72. Thrust washers
73. Gasket
74. Main bearing
75. Bearing support
76. Seal

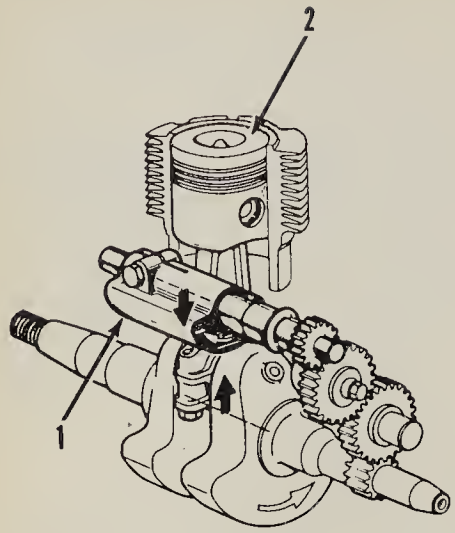


Fig. L4-17—When reinstalling balancer (1), note that balancer weight is down when piston (2) is at top dead center.

Note that roller pin in cam follower is welded to one side of cam follower. Install cam followers so welds are on opposite sides of followers and not together. Install camshaft so timing marks on camshaft, crankshaft and idler gears are aligned. If timing marks are absent, proceed as follows: Position piston at top dead center, then install camshaft so intake cam follower is on opening side of cam lobe (exhaust lobe is adjacent to injection pump lobe). If necessary, remesh gears so cam followers are at same height. Mark gears for future reference.

The push rods are contained in a tube (57–Fig. L4-16) and must cross between cam followers and rocker arms. Push rod nearer cylinder connects intake cam follower and rocker arm while outer push rod connects exhaust cam follower and rocker arm. Push rod tube (57) is sealed by grommets (58) at both ends.

BALANCER

REMOVE AND REINSTALL. To remove balancer weight and shaft, remove crankcase cover (2–Fig. L4-15) and side cover (24). Loosen clamp screw and while holding weight, withdraw balancer shaft (15). Remove balancer weight (17) out side of engine.

Reverse disassembly procedure to install balancer. Note that with piston at top dead center (TDC), balancer weight is down and slightly inclined towards injection pump (Fig. L4-17).

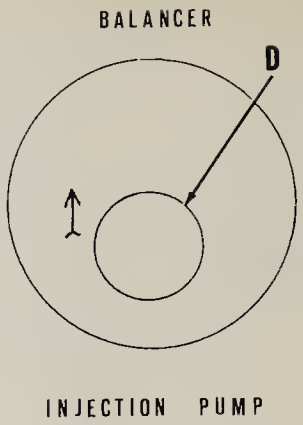


Fig. L4-18—Depression (D) in piston crown should be nearer injection pump and arrow should point towards balancer.

PISTON AND ROD UNIT

Piston and connecting rod may be removed after removing cylinder head and oil pan.

When reinstalling piston and rod, note that depression (D–Fig. L4-18) in piston crown is offset to one side of piston. Install piston so depression side of piston is nearer injection pump side of engine. Some pistons also have an arrow embossed on top of piston. When properly installed, arrow on piston crown will point towards the balancer. Tighten connecting rod cap screws to 49 N·m (36 ft.-lbs.).

Rotate crankshaft to position piston at top dead center. Top of piston should be level with top of cylinder. To adjust, install shim gaskets (60–Fig. L4-16) between cylinder and crankcase as needed.

PISTON, PIN, RINGS AND CYLINDER

The piston is equipped with three compression rings and one oil control ring. On Models 710 and 720, ring end gap should be 0.35-0.55 mm (0.014-0.021 inch) for all compression rings and 0.25-0.40 mm (0.010-0.015 inch) for oil control ring. On all other models, ring end gap should be 0.40-0.65 mm (0.015-0.025 inch) for all compression rings and 0.30-0.60 mm (0.012-0.024 inch) for oil control ring.

To check piston ring groove wear, install new rings onto piston, then measure side clearance between top of ring and top of groove using a feeler gage. Renew piston if clearance exceeds 0.15 mm (0.006 inch) for top compression ring and 0.01 mm (0.004 inch) for all other rings.

Standard piston diameter, measured at bottom of skirt perpendicular to piston pin, is 89.83-89.86 mm (3.5366-3.5378 inches) on Models 710 and 7LD600, 94.83-94.85 mm (3.7335-3.7342

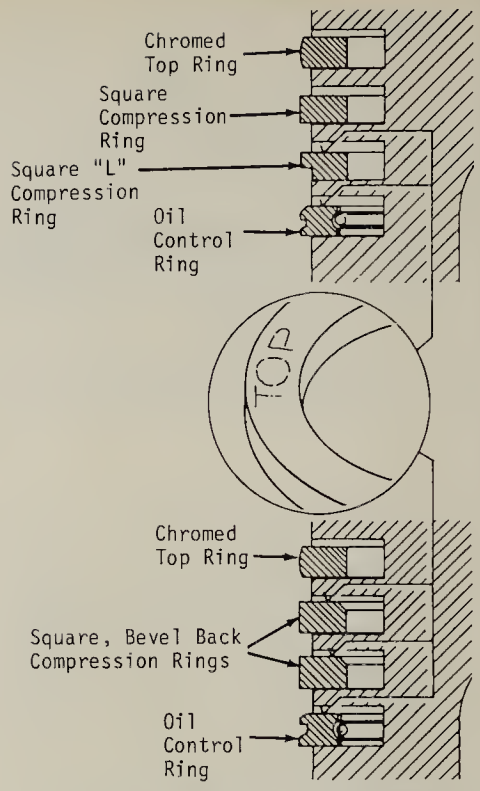


Fig. L4-19—Cross-sectional view of piston and rings showing correct installation.

inches) on Models 720 and 7LD655 or 99.80-99.81 mm (3.9291-3.9295 inches) on Model 7LD740. If wear exceeds 0.05 mm (0.002 inch), renew piston. Oversize pistons and rings as well as standard size are available.

Cylinder bore standard inside diameter is 90.00-90.02 mm (3.5433-3.5441 inches) on Models 710 and 7LD600, 95.00-95.02 mm (3.7401-3.7409 inches) on Models 720 and 7LD655 or 100.00-100.02 mm (3.9370-3.9378 inches) on Model 7LD740. If cylinder bore wear exceeds 0.1 mm (0.004 inch), rebore cylinder to appropriate oversize.

Piston pin diameter is 27.995-28.005 mm (1.1022-1.1025 inches). Clearance between piston pin and connecting rod bushing should be 0.015-0.030 mm (0.0006-0.0012 inch) and maximum allowable clearance is 0.07 mm (0.003 inch).

When installing rings onto piston, stagger ring end gaps 180° apart. Be sure no end gaps are aligned with piston pin bore. Fig. L4-19 shows correct installation of rings on piston.

CONNECTING ROD

The connecting rod small end is fitted with a renewable bushing (65–Fig. L4-16). Clearance between piston pin and rod bushing should be 0.015-0.025

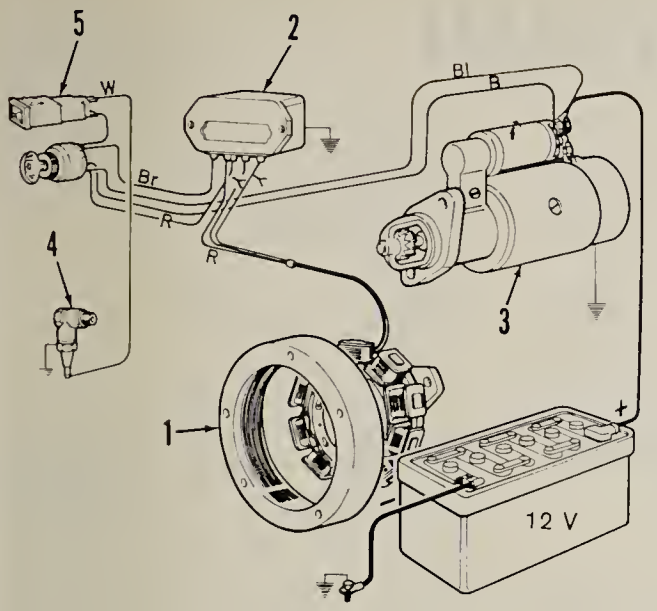


Fig. L4-20—Wiring schematic for models equipped with internal alternator and electric starter.

1. Alternator
2. Regulator
3. Starter motor
4. Oil pressure switch
5. Oil pressure light

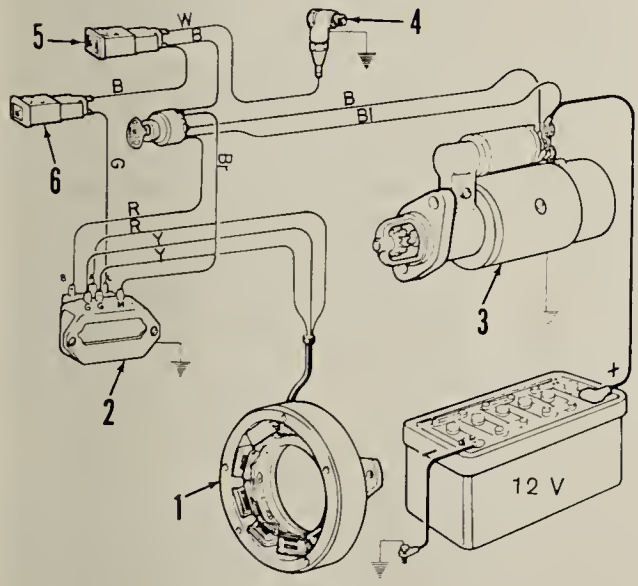


Fig. L4-21—Wiring schematic for models using an alternator warning light (6). Refer to Fig. L4-20 legend.

mm (0.0006-0.001 inch) with a maximum allowable clearance of 0.07 mm (0.003 inch).

An insert type bearing is used in connecting rod big end. Desired rod bearing clearance is 0.03-0.07 mm (0.001-0.003 inch). Maximum allowable clearance is 0.10 mm (0.004 inch). Bearing inserts are available in standard and undersizes. Crankshaft standard crankpin diameter is 49.99-50.00 mm (1.9681-1.9685 inches).

CRANKSHAFT AND CRANKCASE

The crankshaft is supported by sleeve bearings (46 and 74–Fig. L4-16) in the crankcase bulkhead and bearing support (75) and by bearing (4–Fig. L4-15) in the crankcase cover (2).

The crankshaft has drilled oil passages to distribute oil to the bearings. Expansion plugs, located adjacent to crankpin, may be removed to clean oil passages, however, be sure new plugs are installed securely.

On Models 710 and 720, desired bearing clearance for center and flywheel end main bearings is 0.03-0.07 mm (0.001-0.003 inch). On all other models, desired bearing clearance is 0.05-0.07 mm (0.002-0.003 inch). Standard diameter for center and flywheel end main bearing journals is 44.99-45.00 mm (1.7712-1.7716 inches) on all models.

Center and flywheel end main bearings are available in standard size and undersizes. When installing new bearings, be sure lubrication oil holes are aligned. Special bearing installing tool 7271.3595.047 is available from manufacturer.

Renew front oil seal (1–Fig. L4-15) and rear oil seal (76–Fig. L4-16). Be sure to lubricate seal lips prior to reassembly.

Thrust washer (72–Fig. L4-16) thickness should be 2.31-2.36 mm (0.091-0.093 inch). Crankshaft end play is adjusted by varying thickness of support gasket (73). Desired end play is 0.10-0.30 mm (0.004-0.012 inch). Tighten support retaining nuts to 30 N·m (22 ft.-lbs.) and crankcase cover cap screws to 25 N·m (18 ft.-lbs.). Tighten flywheel retaining nut to 295 N·m (217 ft.-lbs.).

ELECTRICAL SYSTEM

Some models are equipped with an alternator, regulator and starting motor. Refer to schematic drawing shown in Fig. L4-20 or L4-21. The alternator stator is attached to the crankcase cover while a ring of magnets is carried by the flywheel.

LOMBARDINI

Model	No. Cyls.	Bore	Stroke	Displ.
8LD600-2, 904	2	90 mm (3.543 in.)	94 mm (3.700 in.)	1196 cc (80 cu. in.)
8LD665-2, 914	2	95 mm (3.740 in.)	94 mm (3.700 in.)	1332 cc (81.3 cu. in.)
8LD665-2/L, L20	2	95 mm (3.740 in.)	94 mm (3.700 in.)	1332 cc (81.3 cu. in.)
8LD740-2	2	100 mm (3.937 in.)	94 mm (3.700 in.)	1476 cc (90 cu. in.)

Engines covered in this section are four-stroke, air-cooled deisel engines. The crankcase and cylinder head are aluminum and the cylinders are cast iron. Crankshaft rotation is counterclockwise at pto end. Number one cylinder is nearer flywheel.

MAINTENANCE

LUBRICATION

Recommended engine oil is SAE 10W for temperatures below 0°C (32°F), SAE 20W for temperatures between 0°C (32°F) and 20°C (68°F), and SAE 40 for temperatures above 20°C (68°F). API classification for oil should be CD. Oil sump capacity is 2.5 liters (2.6 quarts). Manufacturer recommends renewing oil after every 300 hours of operation.

A renewable oil filter is mounted on side of engine crankcase. Manufacturer recommends renewing filter after every 300 hours of operation.

All models are equipped with a pressurized oil system. Refer to Fig. L5-1 for a diagram of the oil circuit.

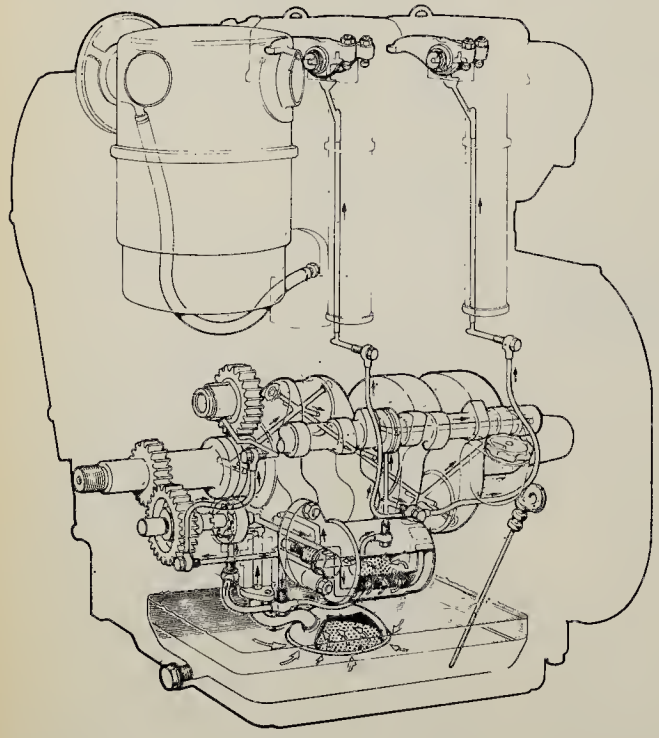


Fig. L5-1—Drawing of lubrication system.

ENGINE SPEED ADJUSTMENT

Low idle speed is adjusted by turning idle speed screw (I—Fig. L5-2). Recommended idle speed is 900-950 rpm on Models 904, 914 and L20; 1000-1200 rpm on Models 8LD600-2, 8LD665-2 and 8LD740-2; or 1100-1400 rpm on Model 8LD665-2/L. Engine should be at normal operating temperature when adjusting engine speeds.

Maximum governed speed is adjusted by turning high speed screw (H). Set high idle (no-load) speed 150 rpm above specified governed full-load speed to compensate for governor droop during

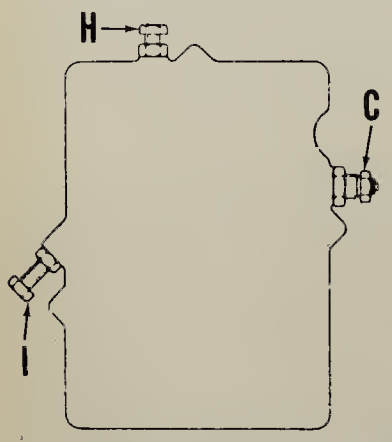


Fig. L5-2—Drawing of governor and throttle control linkage showing location of low idle speed adjusting screw (I), high idle speed adjusting screw (H) and torque control screw (C).

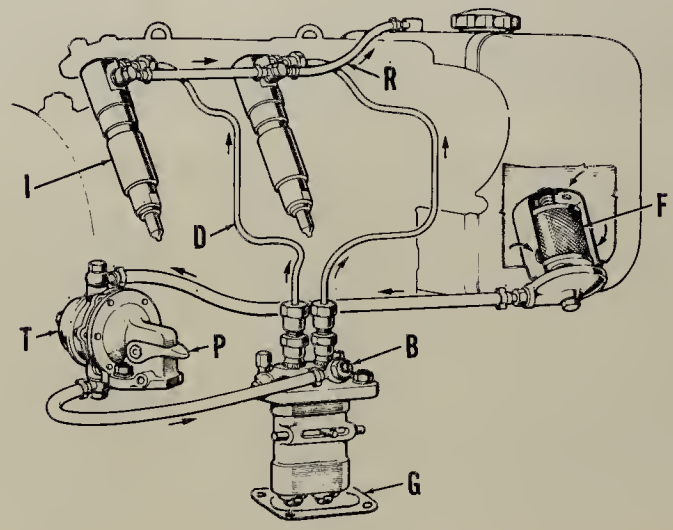


Fig. L5-3—Fuel circuit diagram.

B. Pump bleed screw
D. High pressure delivery line
F. Fuel filter
G. Shim gasket
I. Injector
P. Primer lever
R. Fuel return line
T. Fuel transfer pump

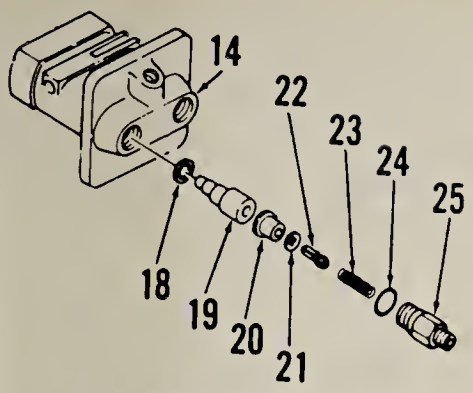


Fig. L5-4—Partial exploded view of fuel injection pump.

14. Pump body
18. Packing
19. Barrel
20. Delivery valve seat
21. Gasket
22. Delivery valve
23. Spring
24. "O" ring
25. Delivery valve holder

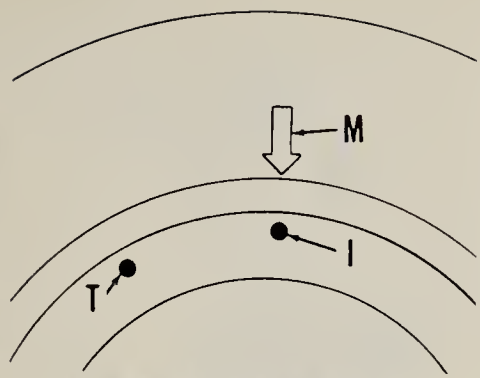


Fig. L5-6—Drawing of crankshaft pulley timing marks used on some models.

I. Injection
M. Reference mark
T. Top dead center

operation. Full-load speed is normally 3000 rpm on all models except 8LD655-2/L and L20, which are limited to 2200 rpm. Governed speed may vary depending upon application.

FUEL SYSTEM

FUEL FILTER. A renewable fuel filter (F–Fig. L5-3) is located in the fuel tank. Manufacturer recommends renewing filter after every 300 hours of operation. However, if engine indicates signs of fuel starvation (loss of power or surging), renew filter regardless of hours of operation. After renewing filter, air must be bled from system as outlined in the following paragraph.

BLEED FUEL SYSTEM. To bleed air from fuel system, first loosen bleed screw (B–Fig. L5-3) on fuel injection pump. Manually operate fuel transfer pump primer lever (P) until air-free fuel flows from bleed screw connection, then retighten bleed screw.

If engine fails to start after performing initial bleeding operation, loosen the high pressure injection lines (D) at the injectors. Rotate engine crankshaft to operate injection pump until fuel is discharged at injector line fittings. Retighten injection lines, then start engine.

INJECTION PUMP TIMING

Injection pump timing is adjusted by changing thickness of shim gaskets (G–Fig. L5-3) between pump body and crankcase mounting surface. Injection should occur at 27°-28° BTDC on Models 904, 914 and L20 or 24°-26° BTDC on all other models.

To check injection pump timing, first disconnect injection line of number 1 cylinder from injection pump delivery valve holder. Unscrew delivery valve holder (25–Fig. L5-4) and remove spring (23) and delivery valve (22). Do not remove delivery valve seat (20). Reinstall delivery valve holder. Move throttle control to full speed position. Operate fuel transfer pump primer lever while rotating crankshaft in normal direction so number 1 piston is on compression stroke. Note that fuel will flow out of delivery valve holder during this procedure. Stop rotating the crankshaft at the moment fuel ceases to flow which is beginning of injection. At this point, timing marks (I and M–Fig. L5-5 or L5-6) should be aligned.

To advance injection timing, remove shim gaskets (G–Fig. L5-3). Increase shim gasket thickness to retard beginning of injection. Tighten injection pump retaining screws to 25 N·m (18 ft.-lbs.). Reinstall delivery valve and tighten delivery valve holder to 34 N·m (25 ft.-lbs.). Bleed air from system as previously outlined.

FAN BELT TENSION

All models are equipped with a belt-driven cooling fan. Belt tension is adjusted by varying the number of shims (2–Fig. L5-7) between fan pulley halves.

COOLING FAN

All models are equipped with an axial cooling fan to force air past the cylinders. The fan housing (4–Fig. L5-7) is mounted on the crankcase. Alternator (7) is contained in the fan housing with the alternator rotor mounted on shaft (6).

Overhaul is evident after inspection of unit and referral to Fig. L5-7.

VALVE CLEARANCE ADJUSTMENT

To adjust valve clearance, first remove rocker arm covers and rotate crankshaft until number 1 piston is at TDC on compression stroke. Clearance between rocker arm and valve stem end should be 0.15 mm (0.006 inch) for both intake and exhaust valves with engine cold. Note that there are two adjusting screws (Fig. L5-8) in exhaust rocker arm. Adjusting screw (V) nearer rocker arm shaft is used to adjust valve clearance while outer screw (C) adjusts compression release.

After adjusting valve clearance on number 1 cylinder, rotate crankshaft

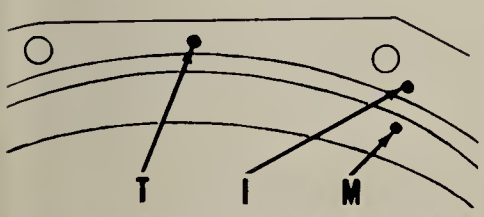


Fig. L5-5—Drawing of flywheel timing marks used on some models.

I. Injection
M. Reference mark
T. Top dead center

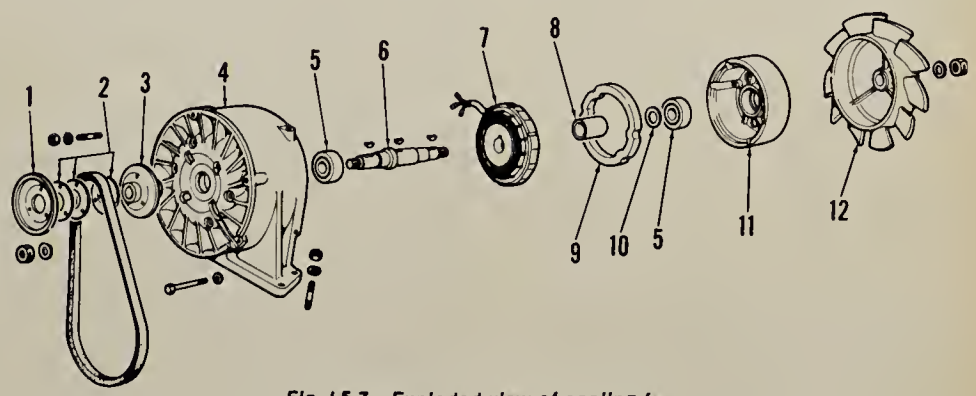


Fig. L5-7—Exploded view of cooling fan.

1. Pulley half
2. Shims
3. Pulley hub
4. Fan housing
5. Bearing
6. Shaft
7. Alternator
8. Spacer
9. Spacer
10. Washer
11. Alternator housing
12. Fan

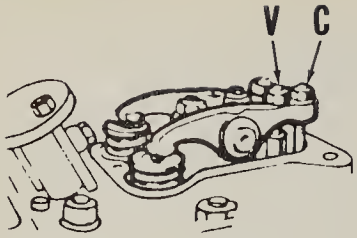


Fig. L5-8—Exhaust valve rocker arm is equipped with two adjusting screws. Inner screw (V) is used to adjust valve clearance and outer screw (C) is used to adjust compression release.

one complete revolution and adjust valves on number 2 cylinder.

COMPRESSION RELEASE

A manual compression release is located on each cylinder head so the exhaust valve can be held open to aid starting. Rotating shaft (28–Fig. L5-9) forces the exhaust rocker arm to slightly open the exhaust valve.

REPAIRS

TIGHTENING TORQUES

Refer to the following table for tightening torques.

Camshaft gear	195 N·m (145 ft.-lbs.)
Camshaft retainer	25 N·m (18 ft.-lbs.)
Connecting rod	49 N·m (36 ft.-lbs.)
Crankshaft pulley	440 N·m (325 ft.-lbs.)
Cylinder head	60 N·m (44 ft.lbs.)
Flywheel	295 N·m (220 ft.-lbs.)
Injection pump	25 N·m (18 ft.-lbs.)
Injector retainer	10 N·m (8 ft.-lbs.)
Main bearing support:	
Center	40 N·m (30 ft.-lbs.)
End	25 N·m (18 ft.-lbs.)
Oil pan	25 N·m (18 ft.-lbs.)
Oil pump	25 N·m (18 ft.-lbs.)
Oil pump gear	44 N·M (33 ft.-lbs.)
Rocker arm shaft	25 N·m (18 ft.-lbs.)
Timing gear cover	25 N·m (18 ft.-lbs.)

The compression release is adjusted by turning outer adjusting screw (C–Fig. L5-8) in exhaust valve rocker arm. Adjust compression release gap AFTER adjusting exhaust valve clearance. With compression release lever in disengaged position, clearance between adjusting screw and shaft should be 0.9-1.1 mm (0.035-0.043 inch).

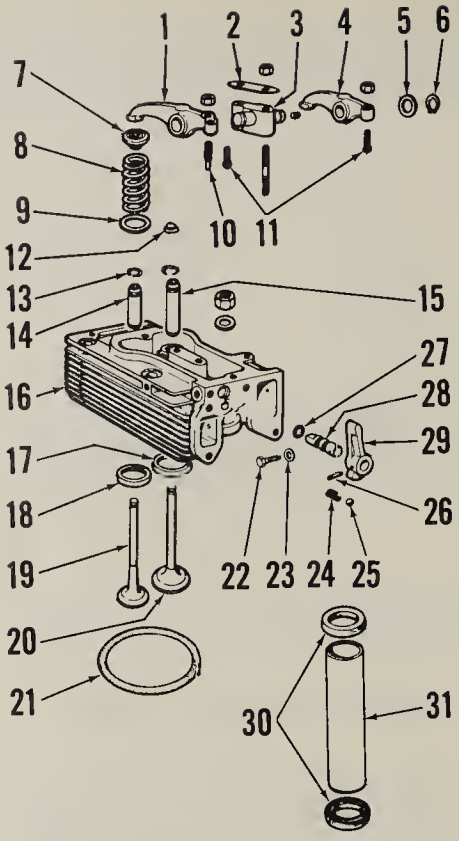


Fig. L5-9—Exploded view of cylinder head.

1. Exhaust rocker arm
2. Lockplate
3. Rocker arm stand
4. Intake rocker arm
5. Washer
6. Snap ring
7. Spring retainer
8. Valve spring
9. Spring seat
10. Compression release adjusting screw
11. Valve adjusting screws
12. Oil seal
13. Snap ring
14. Exhaust valve guide
15. Intake valve guide
16. Cylinder head
17. Intake valve seat
18. Exhaust valve seat
19. Exhaust valve
20. Intake valve
21. Head gasket
22. Locating screw
23. Washer
24. Spring
25. Detent ball
26. Pin
27. "O" ring
28. Compression release shaft
29. Compression release lever
30. Seals
31. Push rod tube

CYLINDER HEAD AND VALVE SYSTEM

Cylinder head should not be removed when engine is hot as head may warp. If cylinder head mounting surface is warped or pitted, up to 0.3 mm (0.012 inch) of material may be lapped from head to true the surface.

Valve face angle is 45° for intake and exhaust. Renew valve if head margin is less than 0.5 mm (0.020 inch). Valve seat angle is also 45° and recommended seat width is 1.4-1.6 mm (0.055-0.065 inch). Renewable valve seat inserts are used on intake and exhaust. Before installing new inserts, cylinder head should first be heated to 160°-180°C (320°-355°F).

With valves installed, measure distance valve head is recessed from cylinder head surface. Intake valve should be recessed 0.60-0.80 mm (0.024-0.031 inch) and exhaust valve (without compression release) should be recessed 0.75-1.25 mm (0.030-0.049 inch). With compression release, exhaust valve recession should be 0.55-0.95 mm (0.022-0.037 inch). If recession is less than specified, regrind valve seat. If recession exceeds specified limit, renew valve seat insert.

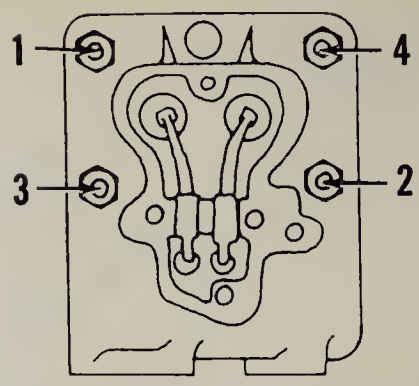


Fig. L5-10—Use a crossing pattern when tightening cylinder head nuts. Tighten nuts evenly in steps to a final torque of 60 N·m (44 ft.-lbs.).

Valve stem diameter is 7.98-8.00 mm (0.314-0.315 inch). Desired valve stem clearance in guide is 0.03-0.08 mm (0.001-0.003 inch) and maximum allowable clearance is 0.15 mm (0.006 inch). Valve guides are renewable and oversize guides are available. Outer diameter of oversize guide must be machined to provide a 0.05-0.06 mm (0.0020-0.0023 inch) interference fit in cylinder head bore. Cylinder head should be heated to 160°-180°C (320°-355°F) prior to installing new guides. Use suitable installing tool when installing new guides to prevent damage to guide. After installation, check inside diameter of guide and ream, if necessary, to provide specified clearance for valve stem. A valve stem seal is used on intake valve.

Intake and exhaust valve springs are identical. Spring free length should be 52 mm (2.047 inches). Valve spring pressure should be 304-323 N (68-72 pounds) when compressed to a length of 25.8 mm (1.015 inches).

Desired clearance between rocker arms and pivot shaft (3–Fig. L5-9) is 0.03-0.06 mm (0.001-0.002 inch). Maximum allowable clearance is 0.1 mm (0.004 inch). Tighten rocker arm shaft retaining nuts to 25 N·m (18 ft.-lbs.).

When reinstalling cylinder head, be sure oil tubes to head are properly connected as shown in Fig. L5-1. Renew push rod tube seals if necessary. Before tightening cylinder head nuts, install exhaust and intake manifolds to correctly position heads. Tighten manifold nuts to 25 N·m (18 ft.-lbs.). Tighten cylinder head nuts gradually using a crossing pattern as shown in Fig. L5-10. Final torque should be 60 N·m (44 ft.-lbs.).

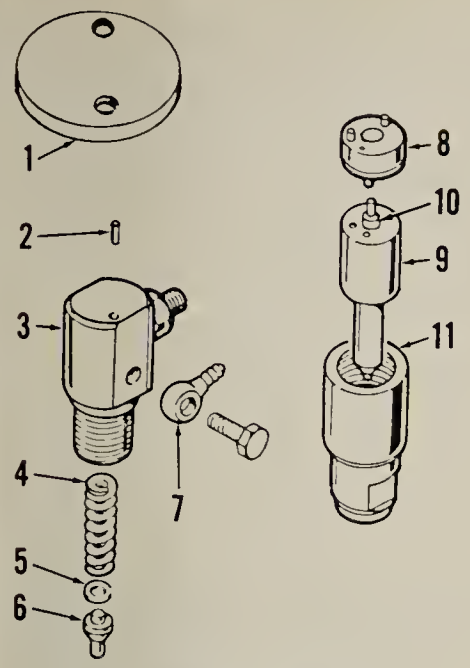


Fig. L5-11—Exploded view of injector.

1. Clamp plate
2. Dowel pin
3. Nozzle body
4. Spring
5. Shim
6. Spring seat
7. Return line fitting
8. Spacer
9. Nozzle
10. Valve
11. Nozzle holder nut

INJECTOR

REMOVE AND REINSTALL. To remove injector, first clean dirt from injector, injection line, return line and cylinder head. Disconnect fuel return line and injection line and immediately cap or plug all openings. Unscrew retainer plate (1 – Fig. L5-11) being careful not to lose dowel pin (2). Injector may now be carefully removed from cylinder head. Do not lose shims between injector and cylinder head.

Tighten injector retainer plate nuts to 10 N·m (8 ft.-lbs.). If accessible, measure protrusion of nozzle into combustion chamber. Nozzle tip should extend 4.0-4.5 mm (0.157-0.177 inch) above adjacent combustion chamber surface. Adjust position of nozzle by installing 0.5 mm (0.020 inch) shims between injector and cylinder head.

TESTING. A suitable test stand is required to check injector operation. Only clean, approved testing oil should be used to test injector.

WARNING: Fuel leaves the injector nozzle with sufficient force to penetrate the skin. When testing, keep yourself clear of nozzle spray.

Connect the injector to tester and operate tester to purge air from nozzle and to make sure nozzle valve is not stuck. When operating properly, injector nozzle will emit a buzzing sound and cut off quickly with no leakage at the tip.

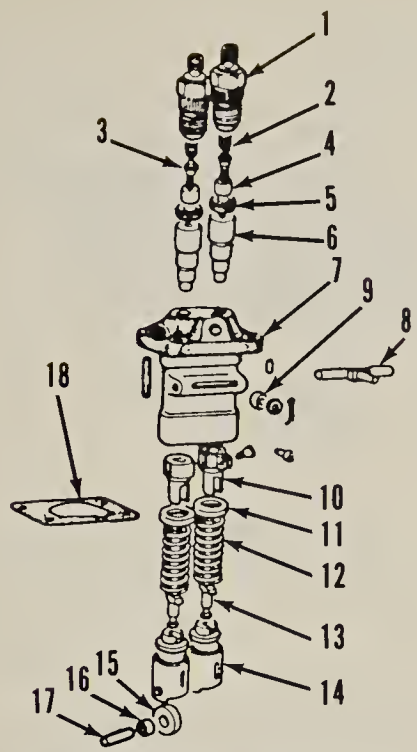


Fig. L5-12—Partially exploded view of fuel injection pump assembly.

1. Delivery valve holder
2. Spring
3. Delivery valve
4. Delivery valve seat
5. Seal
6. Barrel
7. Pump body
8. Control rack
9. Roller
10. Control sleeve & pinion
11. Spring seat
12. Spring
13. Plunger
14. Guide
15. Outer roller
16. Inner roller
17. Pin
18. Shim gasket

Opening pressure should be 20595-21575 kPa (2985-3130 psi) with a used nozzle valve spring (4 – Fig. L5-11). If a new spring is used, opening pressure should be set at 21575-22555 kPa (3130-3270 psi) to compensate for the spring taking a set during operation. Opening pressure is adjusted by varying the number and thickness of shims (5).

Operate tester lever slowly to maintain pressure at 1470 kPa (215 psi) below opening pressure and check for leakage past nozzle valve. If a drop forms at nozzle tip within a 10 second period, nozzle valve must be overhauled or renewed. A slight wetness at tip is permissible.

Operate tester lever briskly and check for an even and well atomized spray pattern. If pattern is wet, ragged or intermittent, nozzle must be overhauled or renewed.

OVERHAUL. To disassemble injector, secure nozzle body (3 – Fig. L5-11) in a vise with nozzle tip pointing upward. Remove nozzle holder nut (11) and withdraw nozzle valve (9 and 10) and spacer (8). Invert nozzle body and remove spring seat (6), shim (5) and spring (4).

Thoroughly clean all parts in a suitable solvent. Do not use a steel wire brush or sharp metal tools to clean injector components. Clean inside the orifice end of nozzle valve with a wooden cleaning stick. The orifice spray holes may be cleaned by inserting a cleaning wire slightly smaller in diameter than the spray hole diameter of 0.28 mm (0.011 inch). Make certain the nozzle needle (10) slides freely in bore of nozzle valve seat (9). If needle sticks, reclean or renew nozzle valve assembly.

When reassembling injector, be sure all parts are clean and wet with diesel fuel. Recheck injector operation as outlined in TESTING paragraph.

INJECTION PUMP

To remove injection pump, disconnect fuel lines and immediately plug all openings to prevent entry of dirt. Remove retaining screws and lift out pump assembly. Be sure to retain pump mounting shim gaskets for use in reassembly. Pump timing is adjusted by changing gasket thickness.

An exploded view of fuel injection pump is shown in Fig. L5-12. It is recommended that injection pump be tested and serviced only by a shop qualified in diesel fuel injection repair.

When reinstalling injection pump, assemble correct thickness of mounting shim gaskets and be sure to engage control rack pin with governor fork. Tighten pump mounting screws to a torque of 25 N·m (18 ft.-lbs.). If pump was overhauled or renewed, check and adjust injection timing as outlined in MAINTENANCE section.

PISTON AND ROD UNITS

REMOVE AND REINSTALL. Piston and connecting rod may be removed after removing cylinder head, oil pan and oil pickup.

When installing piston and rod, note that depression (D – Fig. L5-12A) in piston crown is closer to one side of piston. In-

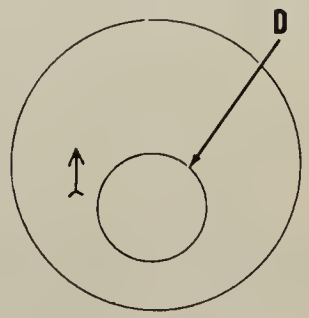


Fig. L5-12A—Arrow on top of piston crown should point towards intake side of engine and depression (D) should be aligned with injector tip.

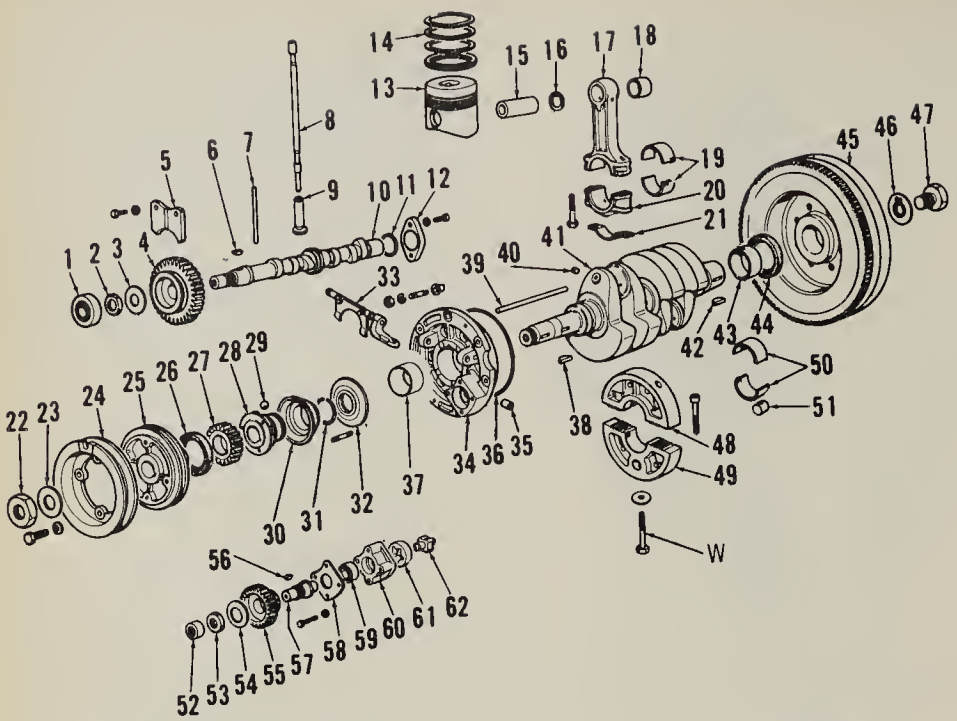


Fig. L5-13—Exploded view of crankshaft, camshaft and oil pump assemblies.

1. Bearing
2. Nut
3. Washer
4. Camshaft gear
5. Retainer
6. Key
7. Fuel pump push rod
8. Push rod
9. Tappet
10. Camshaft
11. "O" ring
12. Cover plate
13. Piston
14. Piston rings
15. Piston pin
16. Snap ring
17. Connecting rod
18. Bushing
19. Rod bearing
20. Rod cap
21. Lockplate
22. Nut
23. Washer
24. Rope pulley
25. Fan pulley
26. Seal
27. Gear
28. Governor hub
29. Balls
30. Governor cup
31. Snap ring
32. Seal
33. Governor arm & shaft
34. End bearing support
35. Bushing
36. "O" ring
37. Main bearing
38. Key
39. Governor rod
40. Plug
41. Crankshaft
42. Key
43. Main bearing
44. Seal
45. Flywheel
46. Lockwasher
47. Cap screw
48. Upper center bearing support
49. Lower center bearing support
50. Center main bearing
51. Round nut
52. Bearing
53. Nut
54. Washer
55. Gear
56. Key
57. Drive shaft
58. Bearing retainer
59. Bearing
60. Oil pump cover
61. Outer rotor
62. Inner rotor
W. Support screw

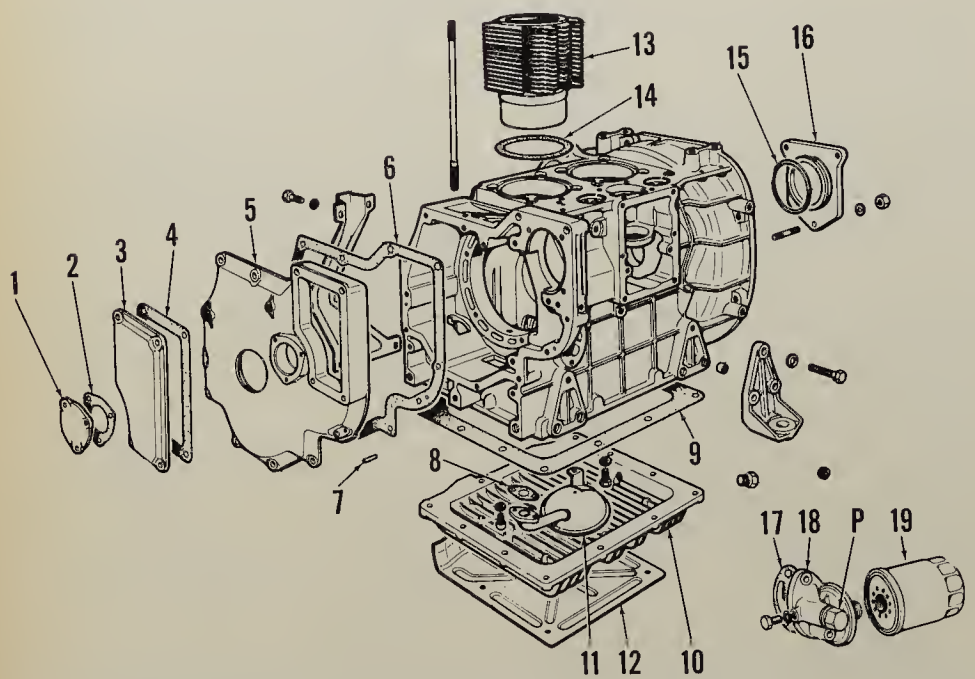


Fig. L5-14—Exploded view of crankcase assembly. Remove plug (P) for access to oil pressure relief valve.

1. Cover
2. Gasket
3. Cover
4. Gasket
5. Timing gear cover
6. Gasket
7. Pin
8. Gasket
9. Gasket
10. Oil pan
11. Oil pickup
12. Air shroud
13. Cylinder
14. Shim gasket
15. "O" ring
16. Cover
17. Gasket
18. Filter adapter
19. Oil filter

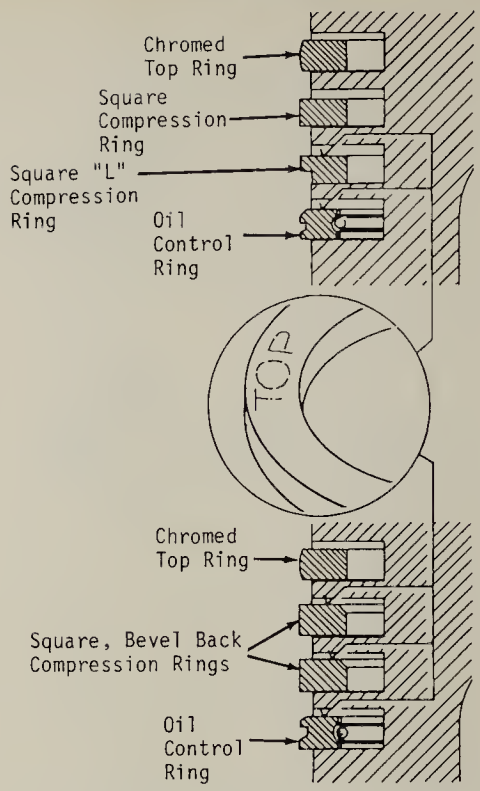


Fig. L5-16—Cross-sectional view of piston and rings showing correct installation of different types of rings.

stall piston so depression side of piston is nearer injector. Some pistons also have an arrow embossed on piston. Properly installed, arrow on piston crown will point toward injection pump. Match alignment marks on rod and cap and tighten rod screws to 49 N·m (36 ft.-lbs.).

Refer to CYLINDER section and measure piston height in cylinder.

PISTON, PIN AND RINGS

The piston is equipped with three compression rings and one oil control ring. On Models 904, 914 and L20, recommended ring end gap is 0.35-0.55 mm (0.014-0.021 inch) for all compression rings and 0.25-0.40 mm (0.010-0.016 inch) for oil control ring. On all other models, ring end gap should be 0.40-0.65 mm (0.016-0.025 inch) for all compression rings and 0.30-0.60 mm (0.012-0.023 inch) for oil control ring.

To check piston ring groove wear, install new rings onto piston, then measure side clearance between top of ring and top of groove using a feeler gage. Renew piston if clearance exceeds 0.15 mm (0.006 inch) for top compression ring and 0.10 mm (0.004 inch) for all other rings.

Standard piston diameter, measured at bottom of skirt perpendicular to piston pin, is 89.85-89.86 mm (3.5374-3.5378 inches) on Model 904; 89.83-89.86 mm (3.5366-3.5378 inches) on Model 8LD600-2; 94.85-94.86 mm (3.7342-3.7346 inches) on Model 914 and

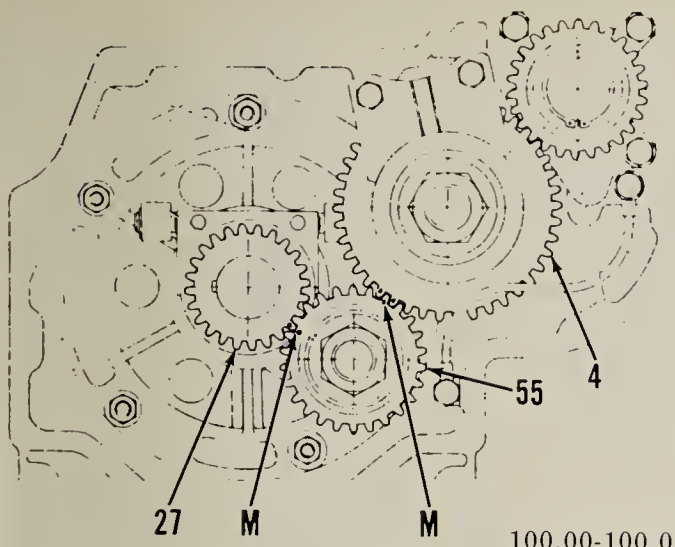


Fig. L5-17—View showing location of timing marks (M) on camshaft gear (4), crankshaft gear (27) and oil pump gear (55).

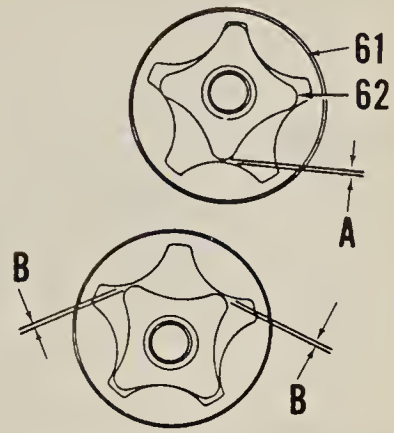


Fig. L5-18—Refer to text for clearances (A and B) between oil pump outer rotor (61) and inner rotor (62).

L20; 94.83-94.85 mm (3.7335-3.7346 inches) on Models 8LD655-2 and 8LD655-2/L and 99.80-99.81 mm (3.9291-3.9295 inches) on Model 8LD740-2. If wear exceeds 0.05 mm (0.002 inch), renew piston. Difference in piston weights must not exceed 6 grams (0.2 ounce).

Piston pin diameter is 27.995-28.005 mm (1.1022-1.1025 inches). Desired clearance between piston pin and connecting rod bushing is 0.015-0.035 mm (0.0006-0.0014 inch). Maximum allowable clearance is 0.07 mm (0.003 inch). Pin should be a thumb press fit piston.

When installing rings onto piston, stagger ring end gaps 180° apart. End gaps should not be in line with piston pin bore. Fig. L5-16 shows correct installation of rings on piston.

CONNECTING ROD

The connecting rod small end is fitted with a renewable bushing. Clearance between piston pin and rod bushing should be 0.015-0.035 mm (0.0006-0.0014 inch) with a maximum allowable clearance of 0.07 mm (0.003 inch).

A precision, insert type bearing is used in crankpin end of connecting rod. Desired rod bearing clearance is 0.03-0.07 mm (0.001-0.003 inch) with a maximum allowable clearance of 0.10 mm (0.004 inch). Bearings are available in standard and undersizes.

Difference in connecting rod weights must not exceed 10 grams (0.35 ounce).

CYLINDERS

All engines are equipped with removable cylinders. Standard cylinder diameter is 90.00-90.02 mm (3.5433-3.5441 inches) for Models 904 and 8LD600-2; 95.00-95.02 mm (3.7401-3.7409 inches) for Models 914, 8LD655-2, 8LD655-2/L and L20; and 100.00-100.02 mm (3.9370-3.9378 inches) for Model 8LD740-2. If cylinder wear exceeds 0.1 mm (0.004 inch), rebore cylinder to the next appropriate oversize.

Cylinder height is adjusted using shim gaskets (14—Fig. L5-14) between bottom of cylinder and crankcase mounting surface. With piston at top dead center, top of piston must be even with top edge of cylinder. Shim gaskets are available in thicknesses of 0.1 and 0.3 mm (0.004 and 0.012 inch). The 0.8 mm (0.031 inch) thick cylinder head gasket ensures adequate clearance between piston crown and cylinder head.

TIMING GEARS

REMOVE AND REINSTALL. Remove belt guard and fan belt. Unscrew nut, then using a suitable puller, pull pulley off crankshaft. Remove timing gear cover.

Use a suitable puller to remove gears. Note that retainer (5—Fig. L5-13) must be removed before pulling off camshaft gear (4). When reinstalling camshaft gear, place gear on shaft so retainer groove is out. Align timing marks (M—Fig. L5-17) on models so equipped, when installing gears. If timing marks are not present on timing gears, proceed as follows: The cylinder head, push rod tube and push rods for number 1 cylinder must be removed. Position number 1 piston at top dead center. If not previously removed, detach camshaft gear from camshaft. Rotate camshaft so number 1 cylinder intake valve cam follower is opening (rising) and exhaust valve cam follower is closing (going down), then stop rotation when cam followers are same height from top surface of crankcase. Without disturbing camshaft position, install camshaft gear. Mark crankshaft, oil pump and camshaft gears for future reference. Reinstall cylinder head.

Tighten camshaft gear nut to 195 N·m (145 ft.-lbs.) and oil pump gear nut to 44 N·m (33 ft.-lbs.). Renew crankshaft oil seal, located in timing gear cover, and lubricate seal lip with grease prior to reinstalling timing gear cover. Tighten timing gear cover cap screws to 25 N·m (18 ft.-lbs.).

OIL PUMP

R&R AND OVERHAUL. The oil pump is mounted on end main bearing support (34—Fig. L5-13). To remove pump, remove timing gear cover and oil pump gear (55). Unscrew pump housing screws and disassemble pump.

Refer to Fig. L5-18 and measure clearance between inner and outer rotors (61 and 62). Clearance (A) should be 0.01-0.06 mm (0.0004-0.0023 inch) with a maximum allowable clearance of 0.10 mm (0.004 inch), and clearance (B) should be 0.02-0.10 mm (0.0008-0.004 inch) with a maximum allowable clearance of 0.20 mm (0.008 inch). Width of inner and outer rotors should be 14.95-14.97 mm (0.5886-0.5894 inch) and difference in rotor widths must not be greater than 0.02 mm (0.0008 inch). Outer rotor outer diameter is 40.54-40.57 mm (1.5960-1.5972 inches). Pump housing bore is 40.60-40.63 mm (1.5984-1.5996 inches). Clearance between outer rotor and pump housing bore should be 0.03-0.09 mm (0.001-0.003 inch) with a maximum allowable clearance of 0.13 mm (0.005 inch). With pump cover (60—Fig. L5-13) and bearing retainer (58) installed and retaining screws torqued, inner rotor end play should be 0.03-0.11 mm (0.01-0.004 inch). Inspect bearing (52) in timing gear cover and renew if damaged.

To reassemble oil pump, reverse disassembly procedure. Install outer rotor (61) with rounded outer edge towards pump housing. Apply Loctite to outer surface of bearing (59) outer race. Tighten oil pump screws to 25 N·m (18 ft.-lbs.). Refer to TIMING GEARS sec-

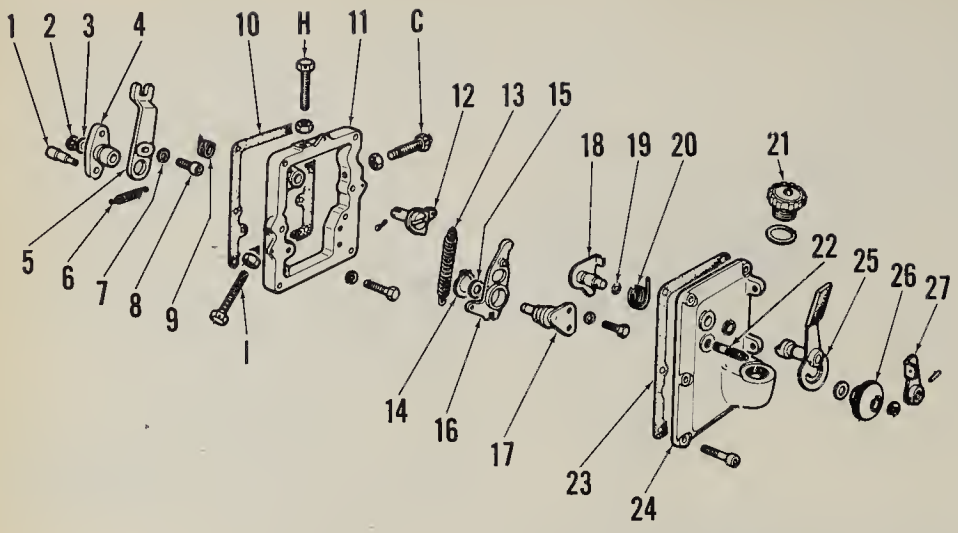


Fig. L5-19—Exploded view of governor and throttle control linkage.

1. Pin
2. Snap ring
3. Washer
4. Pivot flange
5. Governor arm
6. Start spring
7. Washer
8. Allen screw
9. Spring
10. Gasket
11. Plate
12. Pivot arm
13. Governor spring
14. Snap ring
15. Washer
16. Lever
17. Pivot
18. Arm
19. Washer
20. Spring
21. Oil fill cap
22. Stud
23. Gasket
24. Cover
25. Throttle lever
26. Knob
27. Stop lever
C. Torque idle speed screw
H. High idle speed screw
I. Low idle speed screw

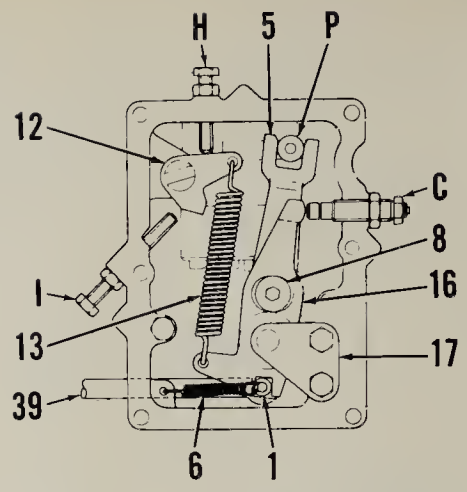


Fig. L5-20—Drawing of governor and throttle control linkage. Refer to Fig. L5-19 legend for parts identification.

tion and align oil pump gear timing marks. Tighten oil pump gear nut to 44 N·m (33 ft.-lbs.).

Oil pressure with engine at normal operating temperature and running at full speed should be 320-350 kPa (45-50 psi). To adjust oil pressure, remove plug (P – Fig. L5-14) from oil filter housing and add or remove shims to vary relief valve spring pressure.

CAMSHAFT AND CAM FOLLWERS

To remove camshaft, first remove cylinder head, push rod tubes and push rods. Remove timing gear cover and camshaft retainer (5 – Fig. L5-13). Remove fuel injection pump and fuel transfer pump. Using suitable tools, raise cam followers away from camshaft. Secure cam followers so they will not fall into crankcase when camshaft is removed. Withdraw camshaft from crankcase.

Inspect front roller bearing (1 – Fig. L5-13) and renew if necessary. Inspect camshaft lobes and bearing journals for wear or other damage. Center bearing journal diameter should be 40.94-40.96 mm (1.6118-1.6126 inches) and rear bearing journal should be 29.94-29.96 mm (1.1787-1.1795 inches) on Models 904, 914 and L20. On all other models, center bearing journal diameter should be 39.94-39.96 mm (1.5724-1.5732 inches) and rear bearing journal should be 27.987-28.000 (1.1018-1.1023 inches). Camshaft operates directly in unbushed bores in crankcase. If journal clearance in crankcase exceeds 0.10 mm (0.004 inch), camshaft and/or crankcase must be renewed.

Cam follower outer diameter is 13.97-13.98 mm (0.5500-00.5504 inch). Clearance in crankcase bore should be 0.02-0.05 mm (0.001-0.002 inch) with a maximum allowable clearance of 0.1 mm (0.004 inch).

Camshaft end play is controlled by retainer plate (5). Camshaft end play should be 0.2-0.4 mm (0.008-0.016 inch). Retainer plate thickness should be 5.7-5.8 mm (0.224-0.228 inch) and groove in camshaft gear (4) should be 6.0-6.1 mm (0.236-0.240 inch). Renew plate and/or gear if end play is excessive.

Tighten camshaft gear retaining nut to a torque of 195 N·m (145 ft.-lbs.) and retainer plate cap screws to 25 N·m (18 ft.-lbs.). Be sure timing marks are aligned as outlined in TIMING GEARS section.

GOVERNOR

All models are equipped with a flyball type governor mounted on the crankshaft. As the flyballs (29 – Fig. L5-13) move in and out against cup (30), fork and lever assembly (33) forces push rod (39) against pin (1 – Fig. L5-19 or L5-20). Pivot flange (4), lever (16) and governor arm (5) are forced to rotate thereby moving fuel injection pump control rack pin (P). Throttle lever (25) operates through pivot arm (12) and governor spring (13) to control engine speed.

The torque control screw (C) limits injection pump fuel delivery at full-load speed. On some models, the control screw tip is spring-loaded to provide additional fuel delivery under maximum load condtions. Spring-loaded torque control screw assembly is calibrated for specific engine application. If device is disassembled, do not change spring washer thickness. Torque control screw is available only as an assembly.

To adjust governor, proceed as follows: With engine stopped, remove cover (24 – Fig. L5-19) and back out torque control screw (C) 5 or 6 turns. Check to be sure start spring (6 – Fig. L5-19 and L5-20) has removed slack in governor mechanism. Loosen governor arm screw (8) and move governor arm (5) towards torque control screw until fuel injection pump control rack pin (P) is in maximum fuel position, then retighten screw. Reinstall control cover and run engine at high idle (no-load) speed. Turn torque control screw (C) in until engine speed just begins to decrease, then turn torque control screw out 2¼ turns on Models L20 and 8LD655-2/L or 1½ turns on all other models. Tighten torque screw locknut.

For access to governor flyball assembly, remove timing gear cover and crankshaft gear.

CRANKSHAFT AND BEARINGS

The crankshaft rides in sleeve bearings in the crankcase bulkhead and end bearing support (34 – Fig. L5-13) and in insert bearings in center support halves 48 and 49).

To remove the crankshaft, remove flywheel, oil pan, cylinder head, pistons and rods and timing gear cover. Using suitable pullers, remove crankshaft gear and governor assembly from crankshaft. Remove end support (34). Remove crankshaft and center support assembly

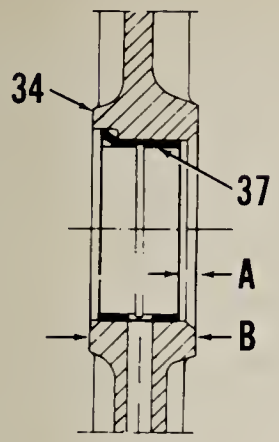


Fig. L5-21—Depth (A) of bearing (37) in end support (34) should be 5 mm (0.020 inch).

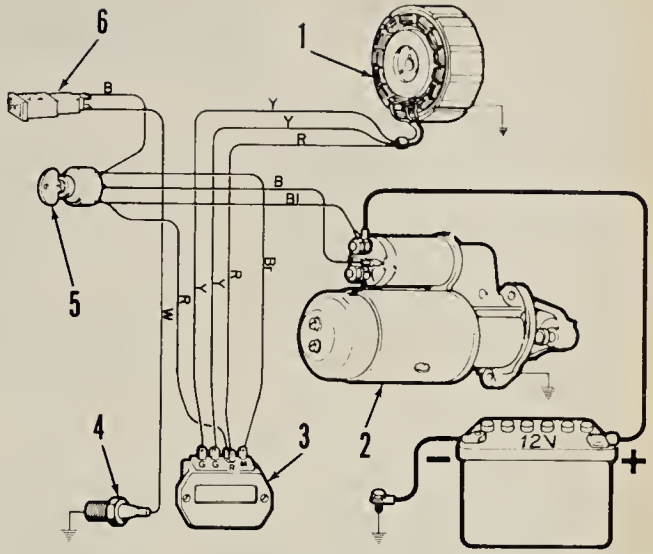


Fig. L5-22—Wiring schematic of models not equipped with an alternator warning light.

1. Alternator assy.
2. Starter motor
3. Regulator
4. Oil pressure sender
5. Switch
6. Oil pressure light

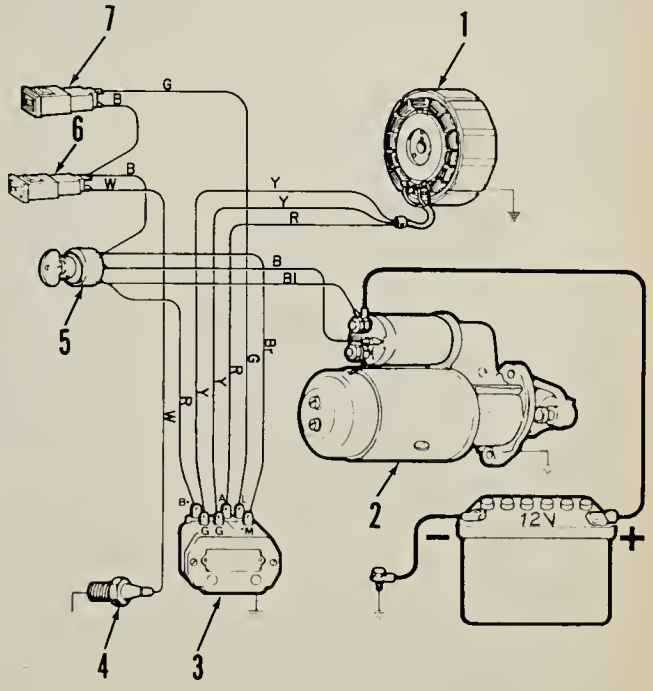


Fig. L5-23—Wiring schematic of models equipped with alternator light (7). Refer to Fig. L5-22 legend.

from crankcase. Unbolt and remove center support halves (48 and 49).

Standard diameter of center main bearing journal is 55.34-55.35 mm (2.1787-2.1791 inches). Standard diameter of outer main bearing journals is 54.94-54.95 mm (2.1630-2.1634 inches). Bearing clearance should be 0.05-0.09 mm (0.002-0.0035 inch) for center main bearing and 0.05-0.07 mm (0.002-0.003 inch) for outer main bearings. Standard and undersize bearings are available.

Standard crankpin journal diameter is 49.99-50.00 mm (1.9681-1.9685 inch). Recommended rod bearing clearance is 0.03-0.07 mm (0.001-0.003 inch) with a maximum allowable clearance of 0.10 mm (0.004 inch). Standard and undersize rod bearings are available.

Serrated parting surfaces of center support halves must be aligned during assembly. With support screws tightened to 25 N·m (18 ft.-lbs.), outside diameter of support should be 154.98-154.99 mm (6.1016-6.1019 inches). Maximum out-of-round is 0.01 mm (0.0004 inch).

Special tool 7271.3595.047 is available from manufacturer to install bearing (37 – Fig. L5-13) in end support (34). When installing bearing, distance (A – Fig. L5-21) from bearing (37) to inside surface of support should be 5 mm (0.020 inch). Make certain lubricating oil holes are aligned.

Crankshaft end play should be 0.15-0.25 mm (0.006-0.010 inch) and is not adjustable. A worn end support (34 – Fig. L5-13) or crankshaft will cause excessive end play.

Reassembly is reverse of disassembly. Be sure to lubricate lip of oil seals (26 and 44) before reinstalling. Tighten screws securing center support halves to 25 N·m (18 ft.-lbs.). Tighten center support assembly mounting screws to 40 N·m (30 ft.-lbs.) and end support cap screws to 25 N·m (18 ft.-lbs.).

ELECTRICAL SYSTEM

Refer to Fig. L5-22 or L5-23 for wiring schematic. Note that circuit in Fig. L5-23 includes an alternator warning light (7) and the voltage regulator is different than the regulator used in circuit shown in Fig. L5-22. The alternator assembly (1) is contained in the fan housing.

LOMBARDINI

Model	No. Cyls.	Bore	Stroke	Displ.
9LD560-2	2	90 mm (3.453 in.)	88 mm (3.464 in.)	1120 cc (68.3 cu. in.)
10LD360-2	2	82 mm (3.228 in.)	68 mm (2.677 in.)	718 cc (43.8 cu. in.)
10LD400-2	2	86 mm (3.386 in.)	68 mm (2.677 in.)	790 cc (48.2 cu. in.)

All engines covered in this section are four-stroke, air-cooled, direct injection diesel engines. The crankcase and cylinder heads are aluminum and the cylinders are cast iron. Crankshaft rotation is counterclockwise at pto end.

MAINTENANCE

LUBRICATION

Recommended engine oil is SAE 10W for temperatures below 0°C (32°F), SAE 20W for temperatures between 0°C (32°F) and 20°C (68°F), and SAE 40 for temperatures above 20°C (68°F). API classification for oil should be CD. Oil sump capacity is 2.8 liters (2.9 quarts) for Model 9LD560-2 and 2.5 liters (2.6 quarts) for all other models. Manufacturer recommends renewing oil after every 300 hours of operation.

A renewable oil filter is located in side of crankcase (Fig. L6-1). Manufacturer recommends renewing filter after every 300 hours of operation.

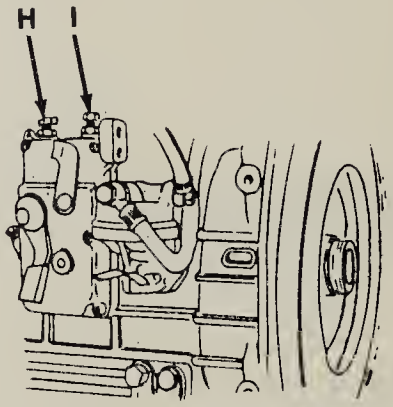


Fig. L6-2—Drawing showing location of low speed adjusting screw (I) and high speed adjusting screw (H).

ENGINE SPEED ADJUSTMENT

Engine should be at normal operating temperature when adjusting engine speed. Low idle speed is adjusted by turning idle speed screw (I – Fig. L16-2). Recommended low idle speed is 1200-1300 rpm.

Maximum governed speed is adjusted by turning high speed screw (H). To compensate for governor droop during operation, set high idle (no-load) speed 180 rpm above specified governed full-load speed on Model 9LD560-2 or 200 rpm above full-load speed on all other models. Specified full-load speed is normally 3000 rpm on Models 9LD560-2 and 10LD400-2. On all other models, full-load speed is normally 3600 rpm. Governed speed may vary depending upon application.

FUEL SYSTEM

FUEL FILTER. A renewable fuel filter (F – Fig. L6-3) is located in the fuel tank. Manufacturer recommends renewing filter after every 300 hours of opera-

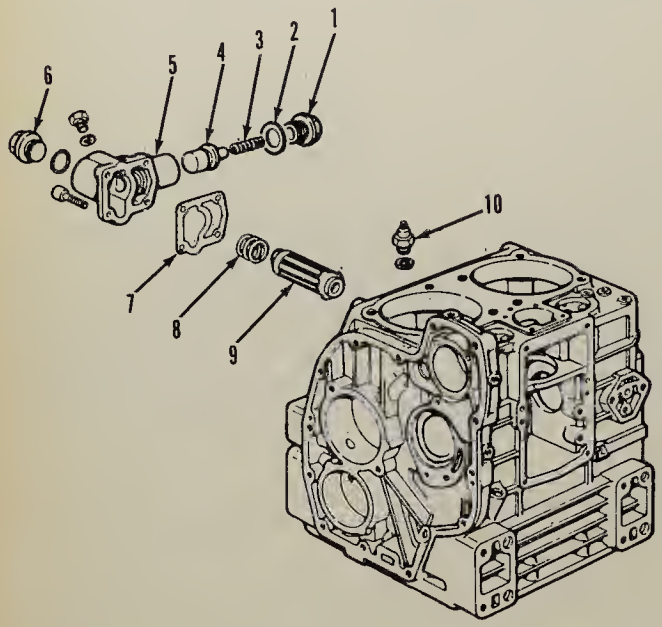


Fig. L6-1—Engine oil filter is located in side of crankcase. Oil pressure relief valve is located in filter housing.

1. Plug
2. Gasket
3. Spring
4. Relief valve poppet
5. Housing
6. Plug
7. Gasket
8. Spring
9. Oil filter
10. Oil pressure sender

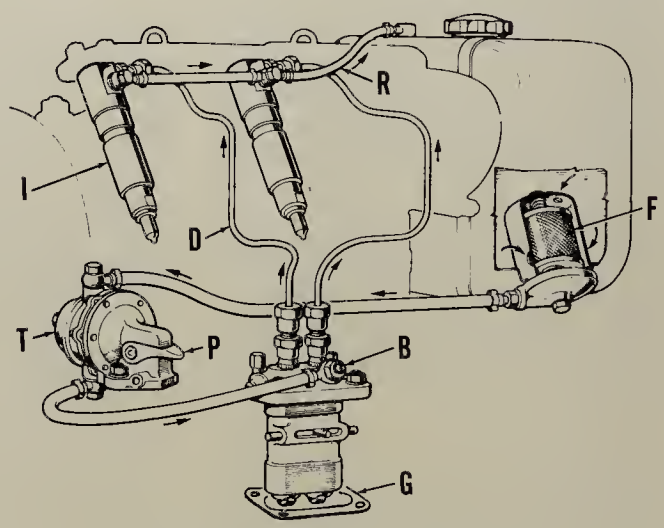


Fig. L6-3—Typical fuel circuit design.

B. Pump bleed screw
D. High pressure delivery line
F. Fuel filter
G. Shim gasket
I. Injector
P. Primer lever
R. Fuel return line
T. Fuel transfer pump

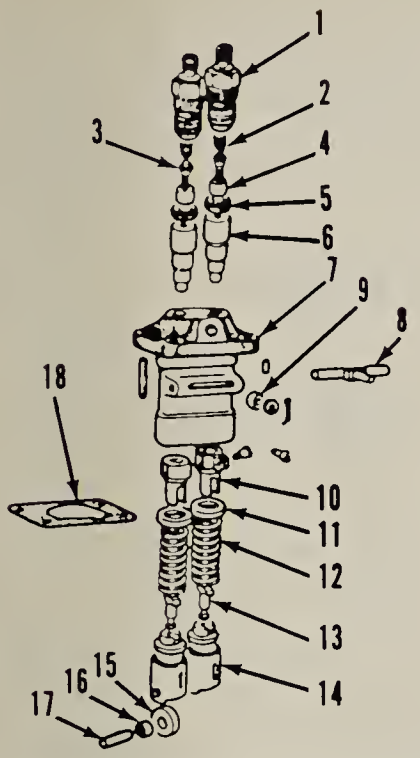


Fig. L6-4—Exploded view of fuel injection pump.

1. Delivery valve holder
2. Spring
3. Delivery valve
4. Delivery valve seat
5. Seal
6. Barrel
7. Pump body
8. Control rack
9. Roller
10. Control sleeve & pinion
11. Spring seat
12. Spring
13. Plunger
14. Guide
15. Outer roller
16. Inner roller
17. Pin
18. Shim gasket

tion. However, if engine indicates signs of fuel starvation (loss of power or surging), renew filter regardless of hours of operation. After renewing filter, air must be bled from system as outlined in the following paragraph.

BLEED FUEL SYSTEM. To bleed air from fuel system, first loosen bleed screw (B—Fig. L6-3) on fuel injection pump. Manually operate fuel transfer pump primer lever (P) until air-free fuel flows from bleed screw connection, then retighten bleed screw.

If engine fails to start after performing initial bleeding operation, loosen the high pressure injection lines (D) at the injectors. Rotate crankshaft to operate injection pump until fuel is discharged at injection line fitting. Retighten injection lines, then start engine.

INJECTION PUMP TIMING

Injection pump timing is adjusted by changing the thickness of shim gaskets (G—Fig. L6-3) between pump body and crankcase mounting surface. Injection should occur at 24°-26° BTDC on all models.

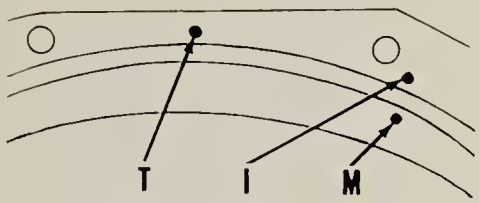


Fig. L6-5—Timing marks (I and M), located in flywheel end of engine, should be aligned when injection to number 1 cylinder occurs. Piston is at top dead center when marks (M and T) are aligned.

To check injection pump timing, first disconnect injection line of number 1 cylinder from injection pump delivery valve holder. Unscrew delivery valve holder (1—Fig. L6-4) and remove spring (2) and delivery valve (3). Do not remove delivery valve seat (4). Reinstall delivery valve holder. Move throttle control to full speed position. Operate fuel transfer pump prime lever while rotating crankshaft in normal direction so number 1 piston is on compression stroke. Note that fuel should be flowing out of delivery valve holder opening during this procedure. Stop rotating crankshaft at the moment fuel ceases to flow from delivery valve. At this point, beginning of injection occurs and timing marks (I and M—Fig. L6-5) should be aligned.

To advance injection timing, reduce shim gasket (18—Fig. L6-4) thickness. Increase shim gasket thickness to retard beginning of injection. Tighten injection pump mounting screws to a torque of 25 N·m (18 ft.-lbs.). Reinstall delivery valve and tighten delivery valve holder to 34 N·m (25 ft.-lbs.). Bleed air from system as previously outlined.

REPAIRS

TIGHTENING TORQUES

Refer to the following table for tightening torques.

Camshaft gear	60 N·m (44 ft.-lbs.)
Connecting rod:	
9LD	30 N·m (22 ft.-lbs.)
10LD	34 N·m (25 ft.-lbs.)
Cylinder head:	
9LD	6 N·m (44 ft.-lbs.)
10LD	44 N·m (33 ft.-lbs.)
Flywheel:	
9LD	295 N·m (215 ft.-lbs.)
10LD	176 N·m (130 ft.-lbs.)
Injection pump	25 N·m (18 ft.-lbs.)
Injector retainer	12 N·m (9 ft.-lbs.)
Main bearing support:	
Center	30 N·m (22 ft.-lbs.)
End	25 N·m (18 ft.-lbs.)
Oil pan	25 N·m (18 ft.-lbs.)
Oil pump:	
9LD	25 N·m (18 ft.-lbs.)
10LD	20 N·m (15 ft.-lbs.)
Oil pump gear	34 N·m (25 ft.-lbs.)
Rocker arm shaft	25 N·m (18 ft.-lbs.)
Timing gear cover	25 N·m (18 ft.-lbs.)

VALVE CLEARANCE ADJUSTMENT

To adjust valve clearance, first remove rocker arm cover and rotate crankshaft until number 1 piston is at TDC on compression stroke. Clearance between rocker arm and valve stem end should be 0.15-0.20 mm (0.006-0.008 inch) for both intake and exhaust valves with engine cold. After adjusting valve clearance on number 1 cylinder, rotate crankshaft one complete revolution and adjust valves on number 2 cylinder.

CYLINDER HEAD AND VALVE SYSTEM

Cylinder head should not be removed when engine is hot as head may warp. If cylinder head mounting surface is warped or pitted, up to 0.3 mm (0.012 inch) of material may be lapped from head to true the surface.

Valve face angle is 45° for intake and exhaust. Renew valve if head margin is less than 0.5 mm (0.020 inch). Valve seat angle is also 45° and recommended seat width is 1.4-1.6 mm (0.055-0.065 inch). Renewable valve seat inserts are used on intake and exhaust. Before installing new inserts, cylinder head should first be heated to 160°-180°C (320°-355°F).

With valves installed, measure distance valve head is recessed from cylinder head surface. Intake valve should be recessed 0.60-0.80 mm (0.024-0.031 inch) and exhaust valve (without compression release) should be recessed 0.80-1.25 mm (0.031-0.049 inch) on Model 9LD560-2 or 0.75-1.20

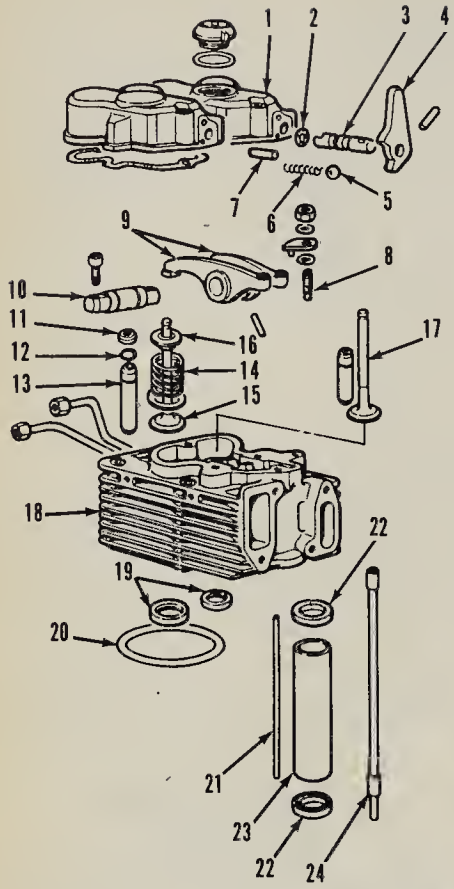


Fig. L6-6—Exploded view of cylinder head assembly.

1. Rocker arm cover
2. "O" ring
3. Compression release shaft
4. Compression release lever
5. Detent ball
6. Spring
7. Pin
8. Adjusting screw
9. Rocker arms
10. Rocker arm shaft
11. Oil seal (intake only)
12. Snap ring
13. Valve guide
14. Valve spring
15. Intake valve
16. Spring retainer
17. Exhaust valve
18. Cylinder head
19. Valve seat inserts
20. Cylinder head gasket
21. Push rod
22. Oil seals
23. Push rod tube
24. Oil supply tube

mm (0.030-0.049 inch) on Model 9LD560-2 or 0.75-1.20 mm (0.030-0.047 inch) on all other models. With compression release, exhaust valve recession should be 0.55-0.95 mm (0.022-0.037 inch) on all models. If recession is less than specified, regrind valve seat. If recession exceeds specified limit, renew valve seat insert.

Valve stem diameter is 7.98-8.00 mm (0.314-0.315 inch). Desired operating clearance of valve stem in guide is 0.03-0.08 mm (0.001-0.003 inch) and maximum allowable clearance is 0.15 mm (0.006 inch). Valve guides are renewable and oversize guides are available. Outer diameter of oversize guide must be machined to provide a 0.05-0.06 mm (0.0020-0.0023 inch) interference fit in cylinder head bore. Cylinder head should be heated to 160°-180°C (320°-355°F) prior to installing new guides. Use suitable installing tool when installing new guides to prevent damage to guide. After installation, check inside diameter of guide and ream, if necessary, to provide specified clearance for valve stem. A valve stem seal is used on intake valves.

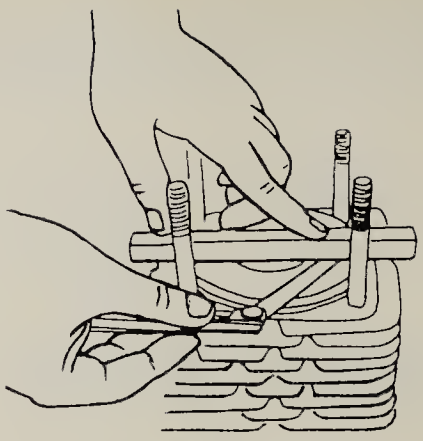


Fig. L6-7—Measure piston height in cylinder and refer to text to determine required cylinder head gasket thickness.

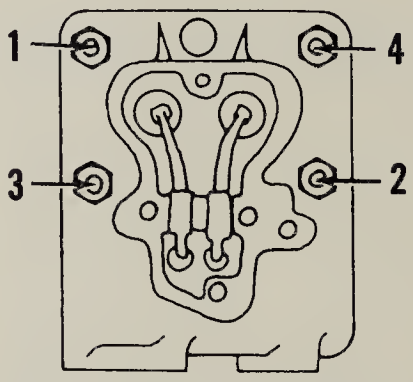


Fig. L6-8—Use a crossing pattern as shown when tightening cylinder head retaining nuts.

Intake and exhaust valve springs are identical. Spring free length should be 52 mm (2.047 inches). Valve spring pressure should be 304-323 N (68-72 pounds) when compressed to a length of 25.8 (1.015 inches).

Desired clearance between rocker arms and pivot shaft (10–Fig. L6-6) is 0.03-0.06 mm (0.001-0.002 inch). Maximum allowable clearance is 0.1 mm (0.004 inch). Tighten rocker arm shaft retaining screws to 25 N·m (18 ft.-lbs.).

The cylinder head gasket is available in varying thicknesses to adjust clearance between cylinder head surface and top of piston. Clearance must be 0.75-0.90 mm (0.030-0.035 inch) on Model 9LD560-2 or 0.70-0.85 mm (0.028-0.033 inch) on all other models. To determine required gasket thickness, position piston at TDC and measure from piston crown to gasket seating surface of cylinder as shown in Fig. L6-7. Subtract the measurement (if piston is below sealing surface) or add the measurement (if piston is above sealing surface) to specified clearance dimension to calculate required gasket thickness.

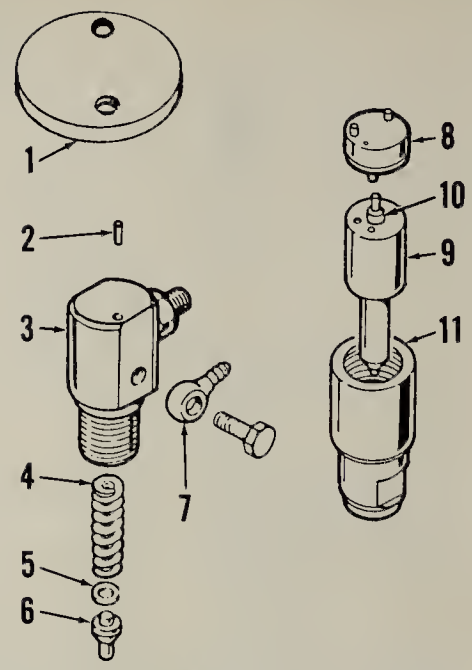


Fig. L6-9—Exploded view of injector assembly.

1. Clamp plate
2. Dowel pin
3. Body
4. Spring
5. Shim
6. Spring seat
7. Return line fitting
8. Spacer
9. Nozzle seat
10. Nozzle valve
11. Nozzle holder nut

When reinstalling cylinder head, attach intake and exhaust manifolds to correctly position cylinder heads before tightening cylinder head nuts. Then, tighten cylinder head nuts in gradual steps using a crossing pattern as shown in Fig. L6-8. Final torque should be 60 N·m (44 ft.-lbs.) on Model 9LD560-2 or 44 N·m (33 ft.-lbs.) on all other models.

INJECTOR

REMOVE AND REINSTALL. To remove injector, first clean dirt from injector, fuel lines and surrounding area. Disconnect fuel return line and high pressure line and plug all openings immediately. Remove retainer plate (1–Fig. L6-9) being careful not to lose dowel pin (2). Withdraw injector from cylinder head. Retain shims between injector and head for use in installation.

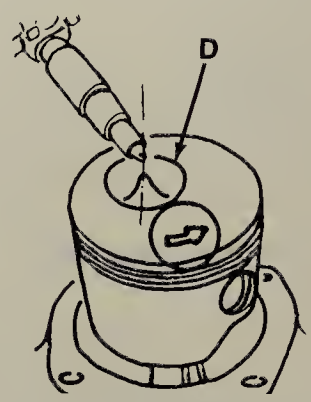


Fig. L6-10—Arrow on piston crown should point towards intake manifold side of engine and depression (D) should be aligned with injector.

If accessible, measure protrusion of nozzle tip into combustion chamber. Nozzle tip should extend 3.0-3.5 mm (0.118-0.138 inch) and may be adjusted by installing 0.5 mm (0.020 inch) shims between injector and cylinder head. Tighten injector clamp plate nuts to 12 N·m (9 ft.-lbs.).

TESTING. A suitable test stand is required to check injector operation. Only clean, approved testing oil should be used to test injectors.

WARNING: Fuel leaves the injector nozzle with sufficient force to penetrate the skin. When testing, keep yourself clear of spray.

Connect injector to tester and operate tester to purge air from nozzle and to make sure nozzle valve is not stuck. When operating properly, injector will emit a buzzing sound and cut off quickly with no leakage at the tip.

Opening pressure should be 20595-21575 kPa (2985-3130 psi) with a used nozzle valve spring (4 – Fig. L6-9). If a new spring is used, opening pressure should be set at 21575-22555 kPa (3130-3270 psi) to compensate for the spring taking a set during operation. Opening pressure is adjusted by varying the number and thickness of shims (5).

Operate tester lever slowly to maintain pressure at 1470 kPa (215 psi) below opening pressure and check for leakage past nozzle valve. If a drop forms at nozzle tip within a 10 second period, nozzle valve must be overhauled or renewed. A slight wetness at the tip is permissible.

Operate tester lever briskly and check for an even and well atomized spray pattern. If pattern is wet, ragged or intermittent, nozzle must be overhauled or renewed.

OVERHAUL. To disassemble injector, secure nozzle body (3 – Fig. L6-9) in a vise with nozzle tip pointing upward. Remove nozzle holder nut (11) and withdraw nozzle valve (9 and 10) and spacer (8). Invert nozzle body and remove spring seat (6), shim (5) and spring (4).

Thoroughly clean all parts in a suitable solvent. Do not use a steel wire brush or sharp metal tools to clean injector components. Clean inside the orifice end of nozzle valve with a wooden cleaning stick. The orifice spray holes may be cleaned by inserting a cleaning wire slightly smaller in diameter than the spray hole diameter which is 0.28 mm (0.011 inch) for Model 9LD560-2 or 0.25 mm (0.010 inch) for all other models. Make certain the nozzle needle (10) slides freely in bore of nozzle valve seat (9). If needle sticks, reclean or renew nozzle valve assembly.

When reassembling injector, be sure all parts are clean and wet with diesel fuel. Recheck injector operation as outlined in TESTING paragraph.

INJECTION PUMP

To remove injection pump, disconnect fuel lines and immediately plug all openings to prevent entry of dirt. Remove retaining screws and lift out pump assembly. Be sure to retain pump mounting shim gaskets (18 – Fig. L6-4) for use in reassembly. Pump timing is adjusted by changing gasket thickness.

It is recommended that injection pump be tested and serviced only by a shop qualified in diesel fuel injection repair.

When reinstalling injection pump, assemble correct thickness of mounting shim gaskets and be sure to engage control rack pin with governor fork. Tighten pump mounting screws to a torque of 15 N·m (18 ft.-lbs.). If pump was overhauled or renewed, check and adjust injection timing as outlined in MAINTENANCE section.

PISTON AND ROD UNITS

The piston and connecting rod may be removed after removing cylinder head and oil pan. Identify piston and rod units as they are removed so units can be reinstalled in their original position.

When installing piston and rod, note that depression (D – Fig. L6-10) in piston crown is closer to one side of piston. Install piston so depression will be aligned with injector. Some pistons also have an arrow embossed on piston. Properly installed, arrow on piston crown will point towards intake manifold side of engine. Tighten connecting rod cap screws to a torque of 30 N·m (22 ft.-lbs.) on Model 9LD560-2 or 34 N·m (25 ft.-lbs.) on all other models.

Clearance between piston crown and cylinder head is adjusted by changing thickness of head gasket. Refer to CYLINDER HEAD section for adjustment procedure.

PISTON, PIN AND RINGS

The pistons are equipped with three compression rings and one oil control ring. On Model 9LD560-2, recommended ring end gap is 0.40-0.65 mm (0.016-0.025 inch) for all compression rings and 0.25-0.40 mm (0.010-0.016 inch) for oil control ring. On all other models, compression ring end gap should be 0.30-0.50 mm (0.012-0.020 inch) and oil control ring end gap should be 0.25-0.50 mm (0.010-0.020 inch).

To check piston ring groove wear, install new rings onto piston, then measure side clearance between top of rings and top of grooves using a feeler gage. Renew piston if clearance exceeds 0.15 mm (0.006 inch) for top compression ring and 0.10 mm (0.004 inch) for all other rings.

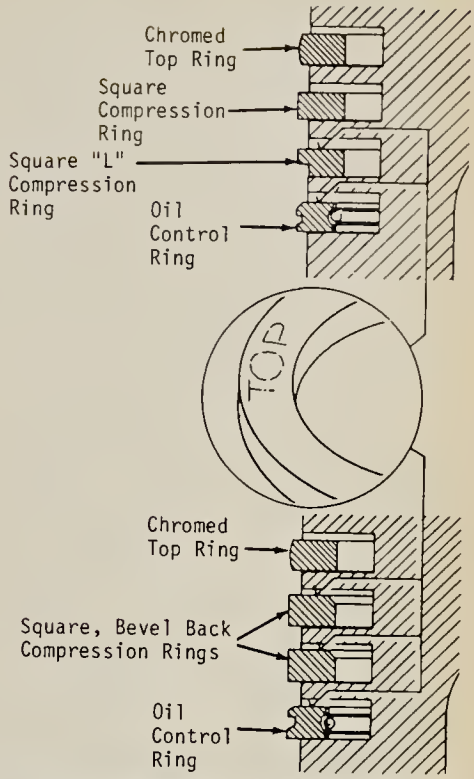


Fig. L6-11—Cross-sectional view of rings and piston showing correct installation of various types of rings.

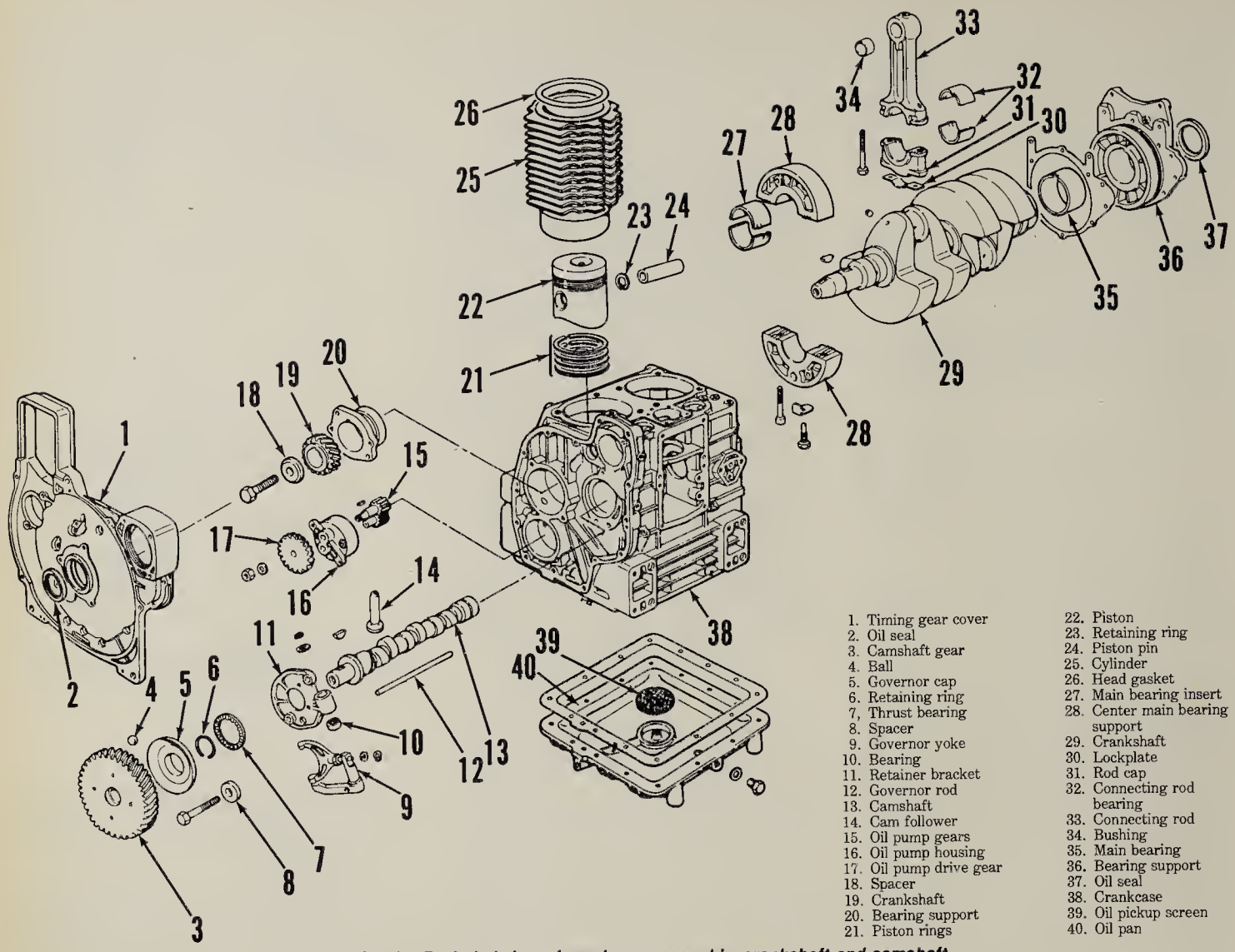
Standard piston diameter, measured at bottom of skirt perpendicular to piston pin, is 89.86-89.88 mm (3.5378-3.5386 inches) for Model 9LD560-2, 81.90-81.92 mm (3.2244-3.2252 inches) for Model 10LD360-2 and 86.00-86.02 mm (3.3858-3.3866 inches) for Model 10LD400-2. If wear exceeds 0.05 mm (0.002 inch), renew piston. Difference in piston weights must not exceed 6 grams (0.2 ounce).

Piston pin diameter is 24.995-25.000 mm (0.9840-0.9842 inch) for Model 9LD560-2 and 19.995-20.000 mm (0.7872-0.7874 inch) for all other models. Clearance between piston pin and connecting rod bushing should be 0.020-0.035 mm (0.0008-0.0014 inch) for Model 9LD560-2 and 0.010-0.030 mm (0.0004-0.0012 inch) for all other models. Maximum allowable clearance is 0.07 mm (0.0027 inch) for all models. Pin should be a thumb press fit in piston.

When installing rings onto piston, stagger ring end gaps 180° apart. Be sure no end gaps are aligned with piston pin bore. Fig. L6-11 shows correct installation of rings on piston.

CONNECTING ROD

The connecting rod small end is fitted with a renewable bushing. Clearance



1. Timing gear cover
2. Oil seal
3. Camshaft gear
4. Ball
5. Governor cap
6. Retaining ring
7. Thrust bearing
8. Spacer
9. Governor yoke
10. Bearing
11. Retainer bracket
12. Governor rod
13. Camshaft
14. Cam follower
15. Oil pump gears
16. Oil pump housing
17. Oil pump drive gear
18. Spacer
19. Crankshaft
20. Bearing support
21. Piston rings
22. Piston
23. Retaining ring
24. Piston pin
25. Cylinder
26. Head gasket
27. Main bearing insert
28. Center main bearing support
29. Crankshaft
30. Lockplate
31. Rod cap
32. Connecting rod bearing
33. Connecting rod
34. Bushing
35. Main bearing
36. Bearing support
37. Oil seal
38. Crankcase
39. Oil pickup screen
40. Oil pan

Fig. L6-12—Exploded view of crankcase assembly, crankshaft and camshaft.

between piston pin and rod bushing should be 0.020-0.035 mm (0.0008-0.0014 inch) for Model 9LD560-2 and 0.010-0.030 mm (0.0004-0.0012 inch) for all other models. Maximum allowable clearance is 0.07 mm (0.0027 inch) for all models.

A precision, insert type bearing is used in crankpin end of connecting rod. Desired rod bearing clearance is 0.05-0.08 mm (0.002-0.003 inch) for Model 9LD560-2 and 0.03-0.06 mm (0.0012-0.0023 inch) for all other models. Bearings are available in standard size and undersizes.

Difference in connecting rod weights must not exceed 10 grams (0.35 ounce) on Model 9LD560-2 or 5 grams (0.18 ounce) on all other models.

CYLINDERS

All models are equipped with removable, cast iron, reborable cylinders. Standard cylinder diameter is 90.00-90.02 mm (3.5433-3.5441 inches) for Model 9LD560-2; 82.00-82.02 mm (3.2283-3.2291 inches) for Model 10LD360-2 and 86.00-86.02 mm (3.3858-3.3866 inches) for Model 10LD400-2. If cylinder wear exceeds 0.1 mm (0.004 inch), rebore cylinder to next appropriate oversize.

TIMING GEARS

REMOVE AND REINSTALL. Remove fan housing, crankshaft pulley, fan and alternator assembly. Unbolt and remove timing gear cover (1–Fig. L6-12). Remove gears from shafts.

When reinstalling gears, be sure timing mark on camshaft gear (3–Fig. L6-13) is aligned with timing marks on crankshaft gear (1). Oil pump gear (2) does not require timing. Tighten camshaft gear cap screw to a torque of 60 N·m (44 ft.-lbs.) and oil pump drive gear retaining nut to 34 N·m (25 ft.-lbs.)

OIL PUMP

The oil pump is mounted in the crankcase and is driven by the crankshaft gear. To remove oil pump, remove timing gear cover (1–Fig. L6-12) and oil pump drive gear (17).

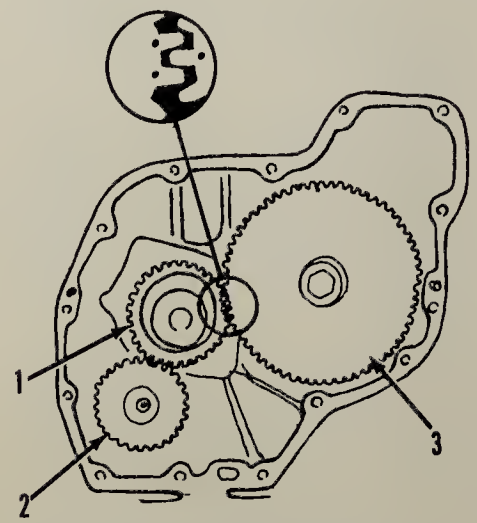


Fig. L6-13—View showing location of timing marks on camshaft gear (3) and crankshaft gear (1).

1. Crankshaft gear
2. Oil pump gear
3. Camshaft gear

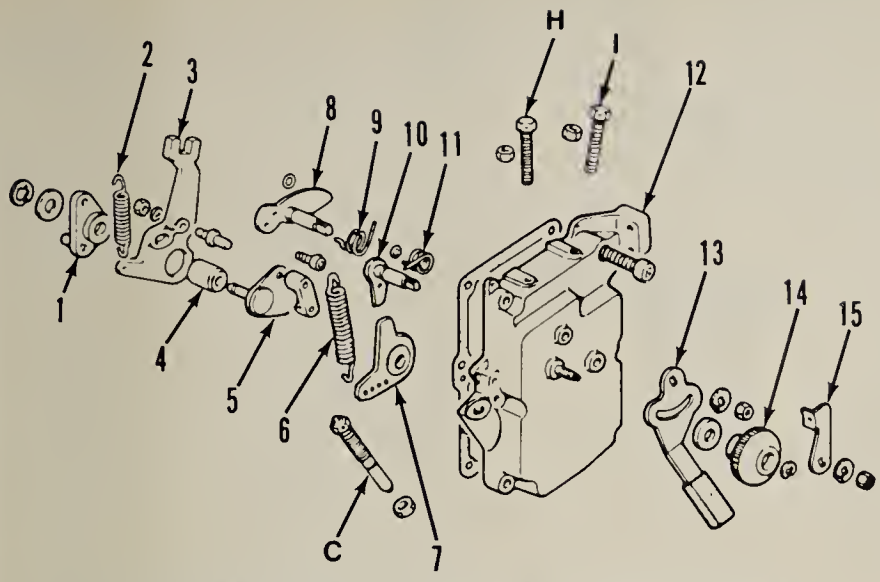


Fig. L6-14—Exploded view of governor and throttle control linkage.

1. Pivot flange
2. Start spring
3. Governor arm
4. Bushing
5. Pivot bracket
6. Governor spring
7. Governor lever
8. Arm
9. Spring
10. Arm
11. Spring
12. Cover
13. Throttle lever
14. Knob
15. Stop lever

C. Torque control screw
H. High idle speed screw
I. Low idle speed screw

Remove pump housing mounting cap screws and withdraw housing (16) and gears (15).

Inspect housing and gears for excessive wear and other damage. Renew pump if clearance between tips of gear teeth and pump body exceeds 0.15 mm (0.006 inch).

To reinstall oil pump, reverse the disassembly procedure. Tighten oil pump cap screws to a torque of 25 N·m (18 ft.-lbs.) on Model 9LD560-2 or 20 N·m (15 ft.-lbs.) on all other models. Tighten oil pump drive gear cap screw to 34 N·m (25 ft.-lbs.).

Oil pressure with engine at normal operating temperature and running at full speed should be 320-350 kPa (45-50 psi). Oil pressure regulating valve (4–Fig. L6-1) is located in oil filter housing mounted on side of crankcase. Pressure regulator valve spring free length should be 37 mm (1.456 inches).

CAMSHAFT AND CAM FOLLOWERS

To remove camshaft, first remove cylinder head, push rod tubes and push rods. Remove timing gear cover, fuel injection pump and fuel transfer pump. Remove camshaft gear (3–Fig. L6-12), governor assembly and retainer bracket (11). Using suitable tools, raise cam followers (14) away from camshaft (13). Secure cam followers so they will not fall into crankcase when camshaft is removed. Withdraw camshaft from crankcase.

Camshaft operates directly in unbushed bearing bores in crankcase. Camshaft center bearing journal diameter should be 39.94-39.96 mm (1.5724-1.5732 inches) and end journal diameter should be 27.987-28.000 mm (1.1018-1.1023 inches). Inspect cam lobes and cam follower surfaces for excessive wear or other damage and renew if necessary. Cam follower outer diameter should be 13.97-13.98 mm (0.5500-0.5504 inch). Desired clearance between cam followers and crankcase bores is 0.02-0.05 mm (0.0008-0.0020 inch) and maximum allowable clearance is 0.10 mm (0.004 inch).

Camshaft end play is controlled by retainer plate (11). Desired end play is 0.10-0.26 mm (0.004-0.010 inch). Tighten retainer plate cap screws to a torque of 25 N·m (18 ft.-lbs.). Tighten camshaft gear cap screw to 60 N·m (44 ft.-lbs.) Tighten camshaft gear cap screw to 60 N·m (44 ft.-lbs.). Be sure timing marks on camshaft gear and crankshaft gear are aligned as shown in Fig. L6-13.

GOVERNOR

All models are equipped with a flyball type governor mounted on the camshaft. As the flyball (4–Fig. L6-12) moves in and out against cup (5), fork assembly (9) forces push rod (12) against pivot flange (1–Fig. L6-14). Pivot flange (1) and governor control arm (3) are forced to rotate thereby moving injection pump control rack. Throttle lever (13) operates through pivot arms and governor spring (6) to control engine speed. Torque control screw (C) limits governor linkage movement thus limiting fuel delivery under full load. Start spring (2) returns the injection pump control rack to maximum fuel delivery position with engine stopped to aid in starting.

To adjust governor, remove cover (12) and back out torque srew (C) about 5 turns. With engine stopped, loosen screw securing governor arm (3) to pivot flange (1). Move governor arm to place injection pump control rack in maximum fuel position and make certain all slack is removed from push rod (12–Fig. L6-12). Retighten governor arm screw. Install control cover, then run engine at full (no-load) speed. Turn torque control screw (C–Fig. L6-14) in until engine speed just begins to decrease, then turn control screw back out 1½ turns.

For access to governor flyball assembly, remove timing gear cover and camshaft gear.

CRANKSHAFT AND BEARINGS

To remove crankshaft, remove flywheel, blower fan (Model 9LD560-2), timing gear cover, oil pan, cylinder head and pistons and connecting rods. Remove crankshaft gear and outer bearing support (20–Fig. L6-12). Remove bearing support (36). Remove center bearing support mounting cap screws, then withdraw crankshaft and center bearing assembly from crankcase. Unbolt and remove center bearing support halves (28) from crankshaft.

Standard diameter of center main bearing journal is 55.34-55.35 mm (2.1787-2.1791 inches). Standard diameters of outer main bearing journals are 54.93-54.95 mm (2.1626-2.1634 inches) and 71.98-72.00 mm (2.8338-2.8346 inches). Recommended bearing clearance is 0.05-0.09 mm (0.002-0.0035 inch) for center main bearing, 0.05-0.08 mm (0.002-0.003 inch) for smaller diameter outer main bearing and 0.07-0.11 mm (0.003-0.004 inch) for larger diameter outer main bearing. Standard and undersize bearings are available.

Standard crankpin diameter is 45.500-45.516 mm (1.7913-1.7919 inches) on Model 9LD560-2 and 39.984-40.00 mm (1.5742-1.5748 inches) on all other models. Recommended rod bearing clearance is 0.05-0.08 mm (0.002-0.003 inch) for Model 9LD560-2 and 0.03-0.06 mm (0.001-0.002 inch) for all other models. Standard and undersize rod bearings are available.

Serrated parting surfaces of center support halves (28) must be aligned during assembly. With support screws tightened to 25 N·m (18 ft.-lbs.), outside diameter of support should be 147.010-147.020 mm (5.7878-5.7882 inches) for Model 9LD560-2 and 128.000-128.018 mm (5.0394-5.0401 inches) for all other models. Maximum allowable out-of-round is 0.01 mm (0.0004 inch).

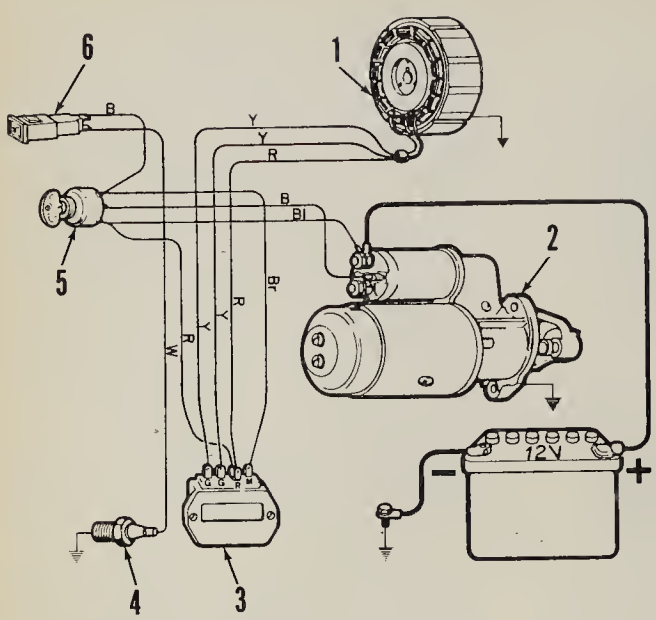


Fig. L6-15—Typical wiring schematic of models not equipped with an alternator light.

1. Alternator
2. Starter motor
3. Regulator
4. Oil pressure switch
5. Switch
6. Oil pressure light

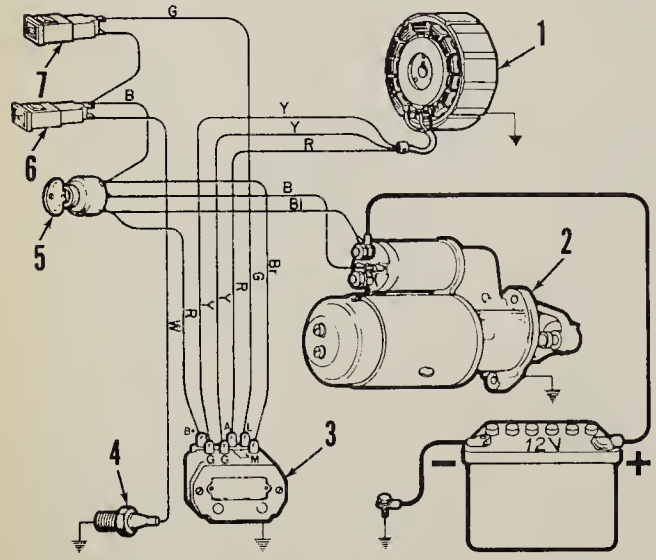


Fig. L6-16—Typical wiring schematic of models equipped with an alternator warning light (7). Refer to Fig. L6-15 legend.

Special tool 7271.3595.047 is available from manufacturer to install bearing (35) in end support (36). When installing bearing, make certain oil hole in bearing is aligned with oil hole in support.

Crankshaft end play should be 0.15-0.30 mm (0.006-0.012 inch) for all other models. End play is adjusted by changing thickness of outer bearing support (36) mounting gasket.

Reassembly is the reverse of disassembly. Be sure to inspect and renew oil seals (2 and 37) if necessary. Lubricate lip of oil seals before reinstalling. Tighten screws securing the center support halves to 25 N·m (18 ft.-lbs.). Tighten center support mounting cap screws to 30 N·m (22 ft.-lbs.) and end support cap screws to 25 N·m (18 ft.-lbs.). Tighten flywheel mounting cap screw to a torque of 295 N·m (215 ft.-lbs.) on Model 9LD560-2 or 176 N·m (130 ft.-lbs.) on all other models.

ELECTRICAL SYSTEM

Refer to Fig. L6-15 or L6-16 for wiring schematic. Note that circuit in Fig. L6-16 includes an alternator warning light (7) and the voltage regulator is different than the regulator used in circuit shown in Fig. L6-15. The alternator assembly (1) is contained in the fan housing.

MWM DIESEL

MWM DIESEL, INC.
3200 Pointe Parkway
Norcross, Georgia 30092

Model	No. Cyls.	Bore	Stroke	Displ.
D202-2	2	95 mm (3.74 in.)	105 mm (4.13 in.)	1490 cc (90.8 cu. in.)
D202-3	3	95 mm (3.74 in.)	105 mm (4.13 in.)	2230 cc (136.2 cu. in.)
D302-1	1	95 mm (3.74 in.)	105 mm (4.13 in.)	750 cc (45.5 cu. in.)
D302-2	2	95 mm (3.74 in.)	105 mm (4.13 in.)	1490 cc (90.8 cu. in.)
D302-3	3	95 mm (3.74 in.)	105 mm (4.13 in.)	2230 cc (136.2 cu. in.)

All MWM (Murphy) engines in this section are four-stroke direct injection diesels with vertical cylinders. D202 engines are liquid-cooled and D302 engines are air-cooled. Crankshaft rotation is counterclockwise viewed from flywheel end on all engines. Firing order is 1-3-2 on three-cylinder engines.

MAINTENANCE

LUBRICATION

Engine crankcase oil must meet API service classification CC/SF, CD/SF, CC or CD. Use of multigrade oil is approved but oil must meet API classification CD/SF or CD. If sulfur content in the fuel exceeds 0.5 percent, a CD or CD/SF oil must be used.

If ambient temperature is permanently below 0°C (32°F), SAE 10W-30 or 5W-20 oil is preferred but SAE 10W may also be used. If temperature varies between minus 10°C (14°F) and 10°C (50°F), SAE 20W-20 is preferred but 15W-40 may be used. If temperature is between 0°C (32°F) and 30°C (85°F), preferred oil is SAE 30 but 15W-40 may be used. If temperature remains above 30°C (85°F), SAE 40 oil is recommended.

Recommended oil change interval is every 250 hours of operation or every six months, whichever occurs first. The oil filter should also be renewed at this time. Manufacturer recommends using only genuine MWM Diesel replacement oil filter.

Standard crankcase capacity with filter change is approximately 4.5 liters (4.7 quarts) for D202-2, 7.75 liters (8.2 quarts) for D202-3, 3.1 liters (3.25 quarts) for D302-1, 5.5 liters (5.8 quarts) for D302-2 and 7.6 liters (8.1 quarts) for D302-3.

With engine warm and running at full speed, normal oil pressure is 400-500 kPa (68-72 psi). An oil pressure relief valve assembly is located in the oil filter mounting housing on D202-3 and D302-3 engines. On all other engines, relief valve assembly is mounted in a drilled passage in the crankcase next to the oil filter.

D302-3 engines are equipped with an engine oil cooler located in the cooling air housing. A cooler bypass valve is set to open at 250 kPa (36 psi) to divert oil from the cooler when oil is cold.

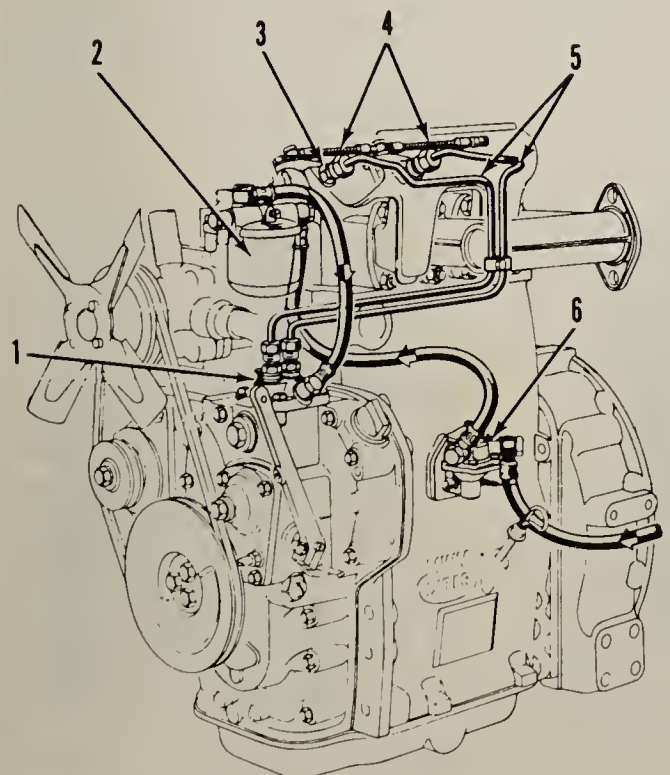


Fig. M1-1—View of typical fuel system components. Some engines are equipped with two fuel filters.

1. Injection pump
2. Fuel filter
3. Injector
4. Fuel leak-off lines
5. High pressure injection pipes
6. Fuel feed pump

FUEL SYSTEM

FUEL FILTER AND BLEEDING. The fuel filter should be renewed after every 1000 hours of operation or sooner if loss of engine power is evident. If engine fails to operate properly after filter element has been renewed, note that there is a filter screen located in the inlet section of fuel feed pump which may become plugged. Screen can be removed and cleaned after removing top cover from fuel feed pump.

Whenever fuel filter is serviced or fuel lines are disconnected, air must be bled from the fuel system in the following manner. Loosen bleed screw on fuel filter mounting base. Operate priming lever on fuel feed pump (6 – Fig. M1-1) until air-free fuel is discharged at bleed screw, then retighten screw. If engine fails to start at this point, loosen high pressure fuel line fittings at the injec-

tors. Position injection pump control in "run" position, then crank engine until fuel is discharged at loosened fittings. Retighten fittings and start engine.

INJECTION PUMP TIMING. To check pump timing, it is first necessary to establish an accurate top dead center for number 1 piston as follows: Remove belt guard and rocker arm cover. Rotate crankshaft until intake valve opens about 5-6 mm (¼ inch), then install special tool M2021 to hold intake valve in the open position. Fabricate a reference timing pointer and install over the front pulley. Rotate crankshaft counterclockwise until piston just contacts the intake valve and scribe a reference mark on front pulley in line with the timing pointer. Rotate crankshaft clockwise until piston contacts intake valve and scribe a second reference mark opposite timing pointer. Select a timing decal from degree decal set number M2010 which matches diameter of front pulley. Position the decal (3 – Fig. M1-2) equally between the two reference marks on the pulley. Remove M2021 tool from intake valve.

Remove the plug, located in front of injection pump, from the timing gear cover. On pumps with Version I or II governors, push injection pump control rack into the pump so it will not be in the "start-fuel" position. On Version III governors, install special tool M2022 (2) in the plug hole until it bottoms to move control rack out of "start-fuel" position. Position throttle at half speed position.

NOTE: Timing cannot be checked with pump control rack in "start-fuel" position as injection timing is retarded approximately 12° in this position.

Disconnect number one injector line at pump, then remove delivery valve holder, spring and delivery valve from pump. Reinstall delivery valve holder with a drip tube (1) if available. Rotate crankshaft about ½ turn counterclockwise. Manually actuate primer lever on fuel feed pump and note that fuel should flow from delivery valve holder, then slowly turn crankshaft clockwise until fuel flow just stops. At this point, port closure occurs and start of injection begins. If timing is correct, the following reading on degree decal should be aligned with timing pointer: 24° BTDC for D202-2, 23° BTDC for D302-1 or 25° BTDC for all other engines.

Pump timing is adjusted by changing thickness of shims (Fig. M1-3) between injection pump and mounting surface of crankcase. Adding shims will retard timing and removing shims will advance timing. Each 0.1 mm (0.004 inch) change in shim thickness will change pump timing about 1°. Shims are available in 0.2 mm (0.008 inch) and 0.3 mm (0.012 inch) thicknesses.

REPAIRS

TIGHTENING TORQUES

Refer to the following table for special tightening torques. All fasteners are metric.

Camshaft nut*	200-210 N·m (148-155 ft.-lbs.)
Connecting rod bolts	
M12-10.9	75-80 N·m (55-59 ft.-lbs.)
M12-12.9	95-100 N·m (70-74 ft.-lbs.)
Crankshaft counterweight	140-150 N·m (104-110 ft.-lbs.)
Crankshaft pulley	120-125 N·m (89-92 ft.-lbs.)
Cylinder head	
D202 engine	170-180 N·m (126-132 ft.-lbs.)
D302 engine	50-55 N·m (37-40 ft.-lbs.)
Flywheel bolts	120-125 N·m (89-92 ft.-lbs.)
Flywheel housing	60-65 N·m (44-48 ft.-lbs.)
Injector retainer	10-15 N·m (8-11 ft.-lbs.)
Main bearing caps	130-140 N·m (96-103 ft.-lbs.)
Oil pan	20-25 N·m (15-18 ft.-lbs.)
Oil pump	20-25 N·m (15-18 ft.-lbs.)
Rocker arm bracket	35-40 N·m (26-29 ft.-lbs.)

*Left-hand threads.

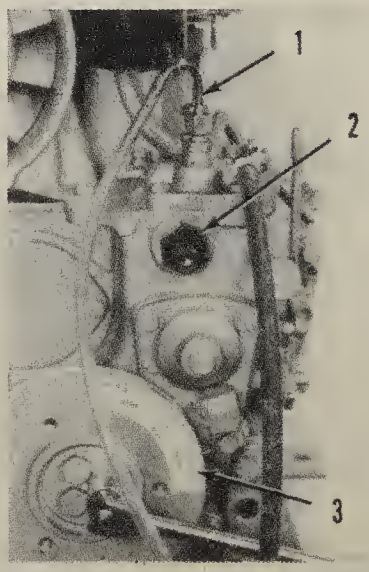


Fig. M1-2—When checking injection timing, install pump rack tool M2022 (2) on engines with Version III governors to move control rack out of automatic "start-fuel" position.

1. Drip tube
2. Pump rack tool M2022
3. Timing decal

COMPRESSION PRESSURE

Compression pressure may be checked to establish relative condition of engine before proceeding with engine disassembly. All injectors should be removed when checking compression pressure. With engine cold, normal compression pressure is 2500-3000 kPa (365-435 psi) at cranking speed. Minimum allowable compression pressure is 2200 kPa (319 psi) and pressure difference between cylinders must not exceed 300 kPa (43 psi). Some causes of low compression pressure are: valves leaking, piston rings worn, cylinder scored or clearance between piston and cylinder head too large.

VALVE ADJUSTMENT

Valve clearance is adjusted with engine cold. Remove rocker arm cover, then turn crankshaft until piston for cylinder being adjusted is at top dead center on compression stroke (both valves closed). Loosen locknut and turn rocker arm adjusting screw until 0.2 mm (0.008 inch) feeler gage can be inserted between rocker arm and valve stem end. Tighten adjusting screw locknut and recheck clearance. Repeat procedure for remaining cylinders. Manufacturer recommends checking valve clearance after every 500 hours of operation.

CYLINDER HEAD

An individual cylinder head is used for each cylinder. Be sure to identify cylinder heads before removal so they can be reinstalled in their original location. Keep shims and gaskets from each cylinder with respective cylinder head for use in reassembly.

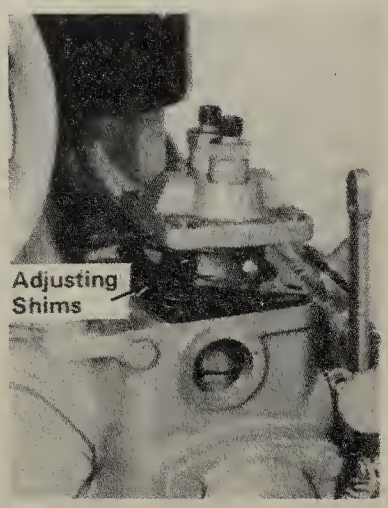


Fig. M1-3—Shims located between injection pump and crankcase mounting surface are used to adjust injection timing.

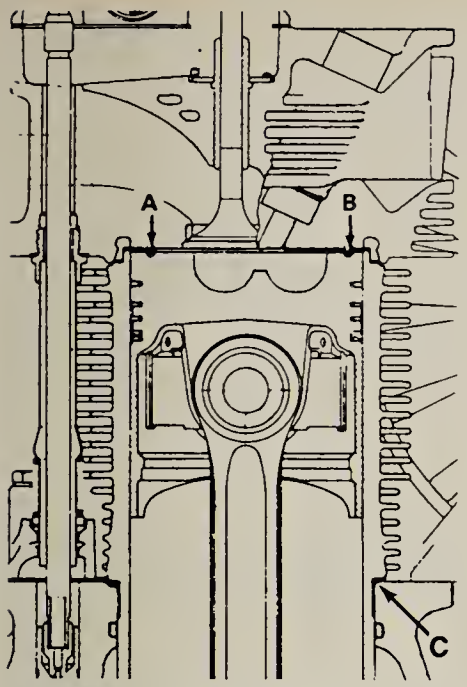


Fig. M1-4—To check piston compression clearance, place lead wires at position "A" and "B" on top of piston. Adjustment on D302 engines is made by changing shim thickness "C". Refer to text.

Clearance between top of piston and cylinder head should be checked as follows: With head removed, place two pieces of lead wire 2 mm (0.080 inch) in diameter at locations (A and B–Fig. M1-4) on piston. Install head with gasket and tighten nuts or bolts to specified torque. Rotate crankshaft by hand until piston has passed top dead center. Remove cylinder and measure thickness of wires. Average thickness of wires should be 0.9-1.2 mm (0.036-0.047 inch). If thickness is not within these specifications on D302 engines, add or remove shims (C) between bottom of cylinder barrel and crankcase. On D202 engines, check rod bearing clearance, piston pin clearance or connecting rod straightness if clearance exceeds specified value.

When reinstalling cylinder head, make certain contact surfaces are clean. On D202 engines, install two M1006 guide studs (or equivalent) diagonally from each other in two cylinder head bolt holes. Note the word "TOP" on head gasket and install accordingly. Position cylinder head over the guide studs and install two bolts (threads oiled) in holes opposite guide studs. Do not install push rods until after cylinder head bolts are tightened. Use a straightedge to align machined surfaces. Remove guide studs and install the other two bolts. Tighten evenly in steps using a criss-cross pattern to 170-180 N·m (126-132 ft.-lbs.). Install push rods and rocker arm assemblies and tighten mounting cap screws to 35-40 N·m (26-29 ft.-lbs.). Run engine for about one hour, then stop and allow to cool. With engine cold, loosen head bolts ¼ turn and retorque to specified setting. Readjust valve clearance.

On D302 engines, install cylinder head with new gasket. Lubricate bottom of stud nuts and threads of nuts and studs with Molykote "G-N" paste or equivalent. Install nuts finger tight, then use a straightedge to align machined surfaces of intake and exhaust port. Tighten nuts evenly in steps using a criss-cross pattern to 45-50 N·m (34-36 ft.-lbs.). Operate engine for about ½ hour, then stop and allow to cool. With engine cold, loosen all nuts ¼ turn and retighten in steps using the criss-cross pattern to 50-55 N·m (37-40 ft.-lbs.) Readjust valve clearance.

VALVE SYSTEM

Intake and exhaust face angle should be 45½° and valve seat angle should be 45°. Valve stem diameter for both valves is 8.952-8.970 mm (0.3525-0.3531 inch) with a wear limit of 8.949 mm (0.3523 inch). Valve guide inner diameter should be 9.013-9.028 mm (0.3548-0.3554 inch) with a wear limit of 9.060 mm (0.3567 inch). When renewing valve guides, cylinder head should first be heated to about 200°C (440°F). After installation, let cool and regrind valve seats.

Desired valve seat width is 2.10-2.45 mm (0.083-0.096 inch). With valves installed, the valve heads should be recessed 1.00-1.45 mm (0.040-0.057 inch) below combustion surface. Maximum allowable valve recession is 1.80 mm (0.071 inch). D302 engines are equipped with renewable valve seat inserts. The inserts are an interference fit in cylinder head counterbores and head should be heated to about 200°C (400°F) prior to installing new inserts.

Rocker arm bracket shaft diameter is 15.966-15.984 mm (0.6286-0.6293 inch) with a wear limit of 15.950 mm (0.6280 inch). Rocker arm bushing inside diameter should be 16.000-16.018 mm (0.6299-0.6306 inch) and maximum allowable diameter is 16.030 mm (0.6311 inch).

INJECTOR

REMOVE AND REINSTALL. To remove injector, disconnect fuel lines and immediately plug all openings to prevent entry of dirt. Remove mounting bracket nuts and withdraw injector and seal washer.

NOTE: Do not reuse nozzle seal washers. When reinstalling new washer, be sure metal side is towards the head.

To reinstall, reverse the removal procedure. Tighten mounting bracket nuts to 10-15 N·m (8-11 ft.-lbs.).

TESTING. A special nozzle tester is required to check injector operation. Injector should be checked for specified opening pressure, nozzle leakage and correct spray pattern.

WARNING: Fuel leaves the injector nozzle with sufficient force to penetrate the skin. When testing, keep yourself clear of nozzle spray.

Connect injector nozzle test pump, then operate tester lever several quick strokes to purge air from injector and to make sure nozzle valve is not stuck. Then operate tester lever slowly while observing tester gage. Nozzle opening pressure should be 18000-18500 kPa (2610-2680 psi) for standard output engines or 22000-22500 kPa (3190-3260 psi) for high output engines. Opening pressure may be adjusted by turning the adjusting screw located at the top of injector.

To check nozzle for leakage, operate tester lever slowly to maintain pressure at 2000 kPa (300 psi) below opening pressure and observe nozzle tip for leakage. If a drop falls from nozzle tip within a 10 second period, nozzle leaks and should be overhauled or renewed. During this test, be careful not to confuse fuel leaking from leak-off fitting at top of injector with leakage at nozzle tip.

To check spray pattern, operate the tester lever several quick strokes (about one stroke per second). All four nozzle spray holes must be open. Spray should be uniform and well atomized and nozzle should emit a "chatter" sound when operating properly.

INJECTION PUMP

The fuel injection pump pumping elements are actuated by lobes on the camshaft. The injection timing is adjusted by varying the thickness of shims located between the pump mounting flange and the crankcase. Refer to MAINTENANCE section for pump timing procedure.

When removing injection pump, be sure to plug all fuel line openings to prevent entry of dirt. It is recommended that injection pump be tested and overhauled only by a shop qualified in diesel fuel injection repair.

When reinstalling pump, use the original mounting shim pack. If shims were misplaced, required shim thickness can be determined as follows: Turn crankshaft until one lobe on camshaft for fuel pump is pointing downward. Measure distance from mounting sur-

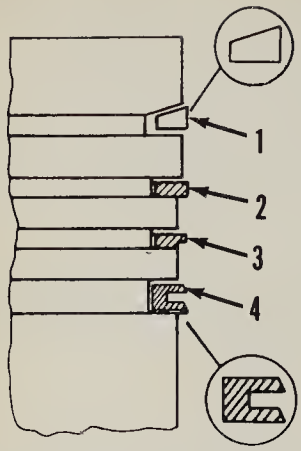


Fig. M1-5—Cross-sectional view of piston and piston rings. Observe "T" or "TOP" mark on rings for correct installation.

1. Keystone top ring
2. Rectangular second compression ring
3. Notched third compression ring
4. Oil control ring

face of crankcase to base of camshaft lobe. Assemble shim thickness necessary to obtain mounting dimension of 82.7-82.9 mm (3.256-3.263 inches). Check injection pump timing as outlined in MAINTENANCE section.

PISTON, PISTON PIN AND RINGS

The piston is equipped with a keystone type top ring (Fig. M1-5), a rectangular second compression ring, a notched third compression ring and an oil control ring. When renewing pistons, note the difference between high output piston (HO–Fig. M1-6) and standard output piston (SO). If converting engine from one piston to the other, be sure to install correct fuel injection nozzles. High output piston should not be used in D302-1 engine.

Piston diameter should be 94.540-94.560 mm (3.7220-3.7228 inches) for all engines. Minimum allowable piston diameter is 94.50 mm (3.7205 inches). Ring groove width should be 3.060-3.080 mm (0.1205-0.1212 inch) for second and third compression rings with

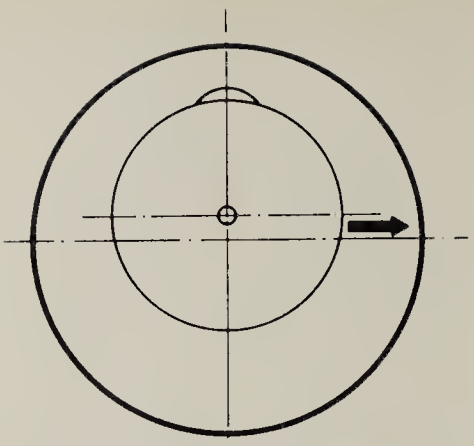


Fig. M1-7—Install piston so arrow on piston crown is pointing towards flywheel end of engine.

a wear limit of 3.120 mm (0.1228 inch). Maximum allowable ring side clearance for second and third rings is 0.20 mm (0.008 inch). Oil control ring groove width should be 5.050-5.070 mm (0.1988-0.1996 inch) with a wear limit of 5.110 mm (0.2012 inch). Oil control ring side clearance in groove should not exceed 0.15 mm (0.006 inch).

With ring positioned squarely in cylinder bore, measure ring end gap with a feeler gage. Desired end gap is 0.40-0.65 mm (0.016-0.026 inch) for all rings and maximum allowable end gap is 2.0 mm (0.079 inch).

The full floating piston pin is retained in the piston by two snap rings. Piston pin diameter is 31.994-32.000 mm (1.2596-1.2598 inches) with a wear limit of 31.990 mm (1.2595 inches). Inner diameter of pin bore in piston should be 32.002-32.006 mm (1.2599-1.2601 inches) with a wear limit of 32.015 mm (1.2604 inches).

When reassembling, be sure to note "T" or "TOP" marking on one side of ring and install with that side facing upward. Refer to Fig. M1-5. Be sure piston is reinstalled with arrow on piston crown pointing towards flywheel end of engine

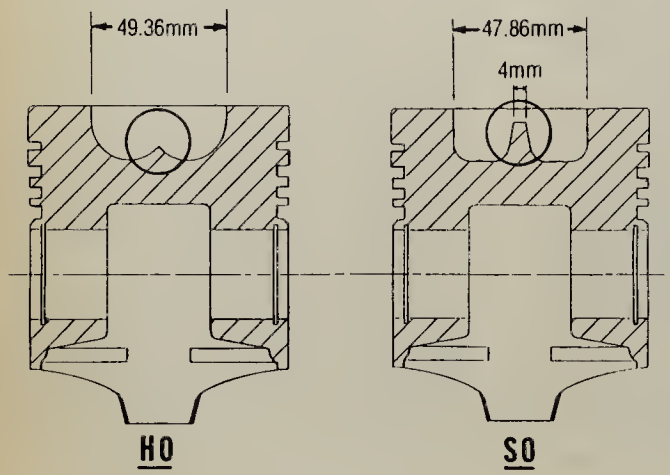


Fig. M1-6—Cross-sectional view of high output (HO) piston and standard output (SO) pistons showing visual differences.

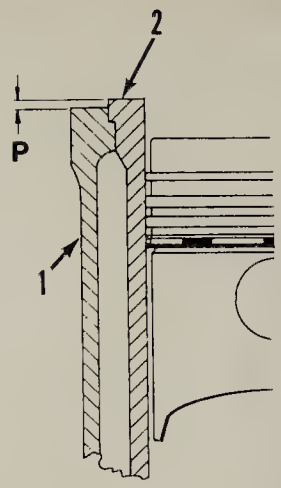


Fig. M1-8—On D202 engines, top of cylinder liner (2) should project (P) 0.05-0.10 mm (0.002-0.004 inch) above crankcase (1) surface when properly installed.

(Fig. M1-7). Check piston height in cylinder as outlined in CYLINDER HEAD section.

CYLINDER

D202 engines are equipped with removable, wet type cylinder liners. D302 engines are equipped with removable, cast iron cylinder barrels.

Standard cylinder bore is 95.000-95.022 mm (3.7402-3.7410 inches) with a wear limit of 95.250 mm (3.750 inches). If excessively worn or scored, cylinders may be rebored for installation of 0.5 mm (0.020 inch) or 1.0 mm (0.040 inch) oversize piston and rings.

On D202 engines, the cylinder liner should project (P–Fig. M1-8) 0.05-0.10 mm (0.002-0.004 inch) above crankcase surface. If liner projection is not within specified limits, check for foreign material between liner flange and crankcase counterbore.

On D302 engines, clearance between piston and cylinder head should be checked as outlined in CYLINDER HEAD section whenever cylinder barrel is renewed. Shims located between bottom of cylinder and crankcase mounting surface are used to adjust piston compression clearance.

CONNECTING ROD

The connecting rod uses a bushing in the small end and a precision, insert type bearing in the big end.

Piston pin bushing inside diameter should be 32.030-32.080 mm (1.2610-1.2630 inches) with a wear limit of 32.150 mm (1.2657 inches). Piston pin outer diameter is 31.994-32.000 mm (1.2596-1.2598 inches). Desired

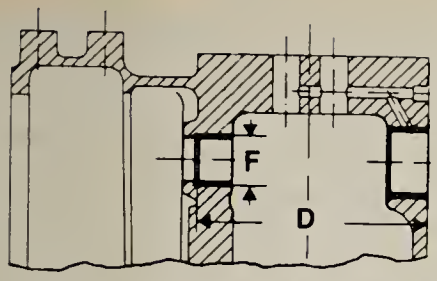


Fig. M1-9—Camshaft bore (F) at flywheel end may be rebored for installation of bushing. End of bore (D) should be 156-157 mm (6.14-6.18 inches) from front surface of crankcase on D302-1 engine. Refer to Fig. M1-10 for all other engines.

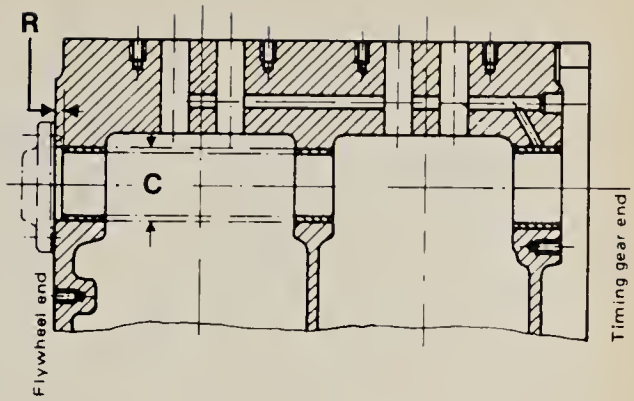


Fig. M1-10—Camshaft bores (C) for two and three-cylinder engines may be bore oversize for installation of bushings. Rear edge of bushings must be recessed (R). Refer to text for details.

clearance between piston pin and bushing is 0.03-0.07 mm (0.0012-0.0027 inch).

Standard diameter of crankpin is 57.951-57.970 mm (2.2815-2.2822 inches). Desired operating clearance for crankpin in rod bearing is 0.07-0.10 mm (0.0027-0.0039 inch). Connecting rod bearing must be renewed when the third layer of bearing material wears off which will be indicated by a shiny bronze contact pattern appearing on bearing surface.

The connecting rod bearing is positioned in big end of rod with locating pin. When assembling connecting rod and bearing, it is recommended that lower half of bearing insert be installed without bearing cap to ensure notch in bearing is indexed with pin. Then, reinstall bearing cap and tighten to 75-80 N·m (55-59 ft.-lbs.) for M12-10.9 bolts or 95-100 N·m (70-74 ft.-lbs.) for M12-12.9 bolts.

CAMSHAFT

The camshaft is supported at the front by a ball bearing located in the crankcase front cover, a renewable bushing in crankcase front bulkhead and directly in bores of crankcase at the rear.

To remove camshaft, first remove cylinder heads and push rods, crankshaft pulley and belt, cooling fan, injection pump, fuel transfer pump and timing gear cover assembly. Use suitable magnetic tools to hold the mushroom type cam followers up away from camshaft assembly. Identify cam followers as they are removed for use in reassembly.

Renew camshaft if bearing journals or cam lobes are scored. Camshaft journal diameter for ball bearing is 24.980-24.993 mm (0.9835-0.9840 inch). Journal diameter at front bushing location is 38.043-38.059 mm (1.4978-1.4984 inches). Bushing inside diameter should be 43.000-43.025 mm (1.6929-1.6939 inches) and maximum allowable inner diameter is 43.050 mm (1.6949 inches). On D302-1 engine, camshaft rear journal diameter is 29.940-29.960 mm (1.1787-1.1795 inches) with a wear limit of 29.920 mm (1.1780 inches). Crankcase bore for rear journal should be 30.000-30.025 mm (1.1811-1.1821 inches) with a wear limit of 30.050 mm (1.1831 inches). On all other engines, diameter of rear journals is 42.940-42.960 mm (1.6906-1.6913 inches) with a wear limit of 42.920 mm (1.6898 inches). Inner diameter of crankcase bores should be 43.000-43.025 mm (1.6929-1.6939 inches) and maximum allowable diameter is 43.050 mm (1.6949 inches).

Cam follower outer diameter should be 17.983-17.994 mm (0.7080-0.7084 inch) with a minimum allowable diameter of 17.975 (0.7077 inch). Cam follower bores in crankcase should be 18.000-18.015 (0.7087-0.7092 inch) with a wear limit of 18.020 mm (0.7094 inch).

If camshaft journals or crankcase bores are excessively worn, the journals can be ground 0.3 mm (0.012 inch) undersize and the crankcase bores at flywheel end can be rebored for installation of bushings. On D302-1 engine, machine crankcase bore (F—Fig. M1-9) inner diameter to 34.000-34.025 mm (1.3386-1.3395 inches). Note that end of bore (D) should be 156-157 mm (6.14-6.18 inches) from front surface of crankcase. On all other engines, machine camshaft bores (C-Fig. M1-10) to inner diameter of 47.000-47.025 mm (1.8504-1.8514 inches). Press rear bushing in until rear edge of bushing is recessed (R) 4 mm (0.157 inch) from rear surface of crankcase. On all engines, make certain oil hole in bushing is aligned with drilled oil passage in crankcase. Bushing inner diameter must be finish machined according to camshaft being installed (new dimensions or undersize). On D302-1 engine, inner diameter of rear bushing should be 30.000-30.021 mm (1.1811-1.1891 inches) for a new camshaft or 29.700-29.721 mm (1.1693-1.1701 inches) for an undersize camshaft. On all other engines, finished size of bushing bore should be 43.000-43.025 mm (1.6929-1.6939 inches) for a new camshaft or 42.700-42.725 mm (1.6811-1.6821 inches) for an undersize camshaft. Be sure to thoroughly clean crankcase after machining is completed.

Camshaft gear is a press fit on camshaft. Heat gear to approximately 220°C (425°F) prior to installation to obtain shrink fit. Note that gear has a scribe mark on hub which must be in line with a scribe mark on camshaft (Fig. M1-11) to provide correct valve timing.

To reinstall camshaft, reverse the removal procedure. Make certain "O" mark on crankshaft gear is meshed with "O-O" mark on camshaft gear.

BALANCE WEIGHT

D302-1 Engine

A counterbalance weight is used on D302-1 engines. Weight and gear may be removed after first removing timing gear cover.

Inspect ball bearing in timing gear cover for wear and renew if needed. Counterweight shaft bushing is a press fit in crankcase. Inside diameter of bushing when new is 32.005-32.030 mm (1.2600-1.2610 inches) and maximum

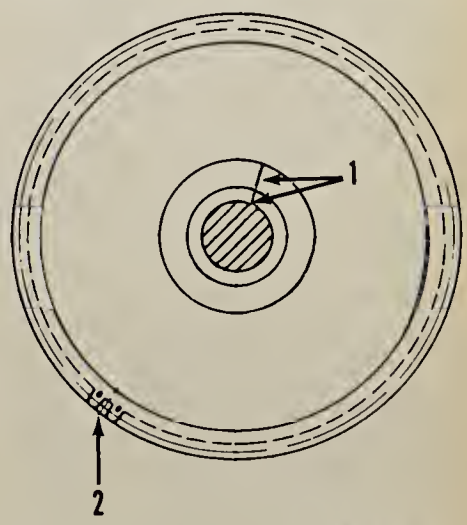


Fig. M1-11—Scribe marks (1) on camshaft and camshaft gear must be aligned when installing gear for correct timing. The "O-O" marks (2) must be aligned with "O" mark on crankshaft gear.

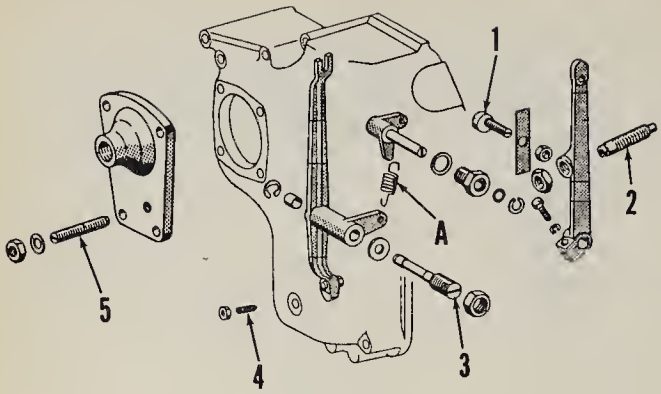


Fig. M1-12—Exploded view of Version I governor linkage and adjustment points.

A. Governor spring
1. High idle adjusting screw
2. Low idle adjusting screw
3. Start-fuel adjusting screw
4. Stop-limit adjusting screw
5. Throttle lock screw

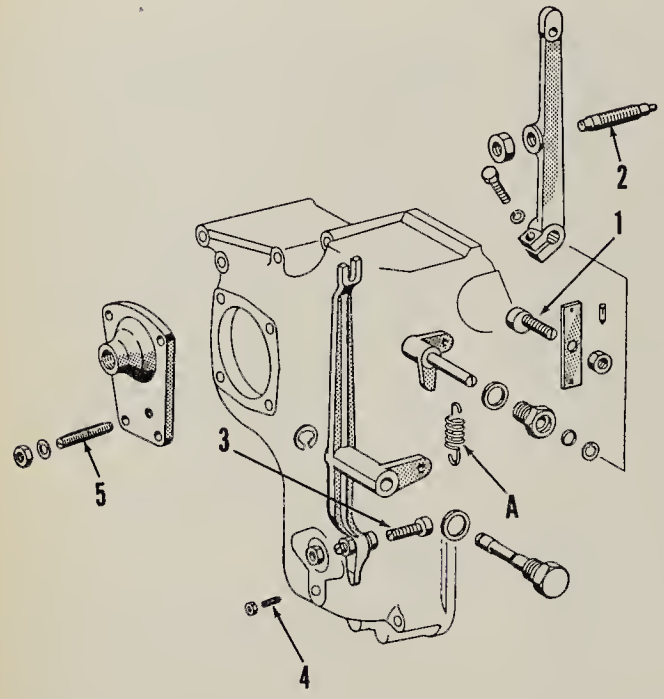


Fig. M1-13—Exploded view of Version II governor linkage and adjustment points. Refer to Fig. M1-12 for identification of components.

allowable bore diameter is 32.100 mm (1.2638 inches). Counterweight shaft outer diameter at bushing end is 31.950-31.975 mm (1.2579-1.2589 inches) with a wear limit of 31.900 mm (1.2559 inches).

Drive gear is a shrink fit on counterweight shaft. Shaft diameter at gear location should be 34.049-34.065 mm (1.3405-1.3411 inches). When renewing gear, first heat gear to about 220°C (425°F). Press gear on shaft making sure scribe mark on face of gear is aligned with "V" notch on counterweight.

Counterweight assembly must be properly timed with crankshaft gear when reinstalled. Make certain the "1" mark on crankshaft gear is aligned between the two chamfered teeth located on back side of counterweight gear. DO NOT use scribe mark on gear for gear timing.

GOVERNOR

The governor flyweight assembly is mounted on the oil pump drive gear. The governor linkage is mounted on the inside of the timing gear cover. For access to governor assembly, remove timing gear cover. Governor components should be checked for excessive wear or binding and renewed if needed.

Three different versions of governor linkage have been used. Refer to Figs. M1-12, M1-13 and M1-14. The main difference between the governors is the Version III contains two springs (A and B – Fig. M1-14) instead of one. The additional spring (B) provides an automatic "start-fuel" feature while a "start-fuel" button is used on the injection pump with Version I and II governors to provide extra fuel delivery during starting.

The other governor spring (A) used on all governors controls the engine operating speed range. Different springs are available for use at a specific speed range. Using a spring in an rpm range that it is not designed for will result in unsatisfactory governor performance. Consult with local engine distributor for listing of different springs and their rpm range. If engine speed range is changed, stamp the new maximum full load rpm on the engine name plate.

Adjustments

HIGH IDLE. The engine high idle (no-load) speed is adjusted using adjusting screw (1 – Fig. M1-12, M1-13 or M1-14) located on timing gear cover behind the throttle lever. An eccentric disc is located on inner end of this screw and only one turn is required to change setting from minimum to maximum. The high idle rpm should be adjusted to 3-5 percent above the maximum rated full load rpm. Specified full load speed is stamped on the engine name plate.

NOTE: If adjusting screw is turned too far in or out, internal governor lever may not contact the eccentric causing governor instability at high rpm. To correct this, proceed as follows:

Remove camshaft cover from timing gear cover and visually observe eccentric. Turn screw in or out as required until proper contact is made with governor lever. Reinstall camshaft cover, then adjust screw to obtain recommended high idle rpm. Install a seal wire to secure screw adjustment.

LOW IDLE. The engine low idle speed is adjusted using adjusting screw (2 – Fig. M1-12, M1-13 or M1-14) located on throttle lever. The adjusting screw also contains a spring-loaded pin which allows throttle lever to be moved past low idle position to shut off fuel delivery. Minimum low idle speed is 650 rpm.

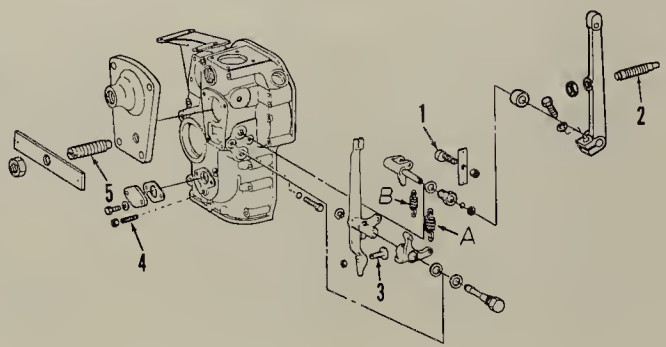


Fig. M1-14—Exploded view of Version III governor linkage and adjustment points. Refer to Fig. M1-12 for identification of components except for the following: Spring (B) provides automatic positioning of pump rack in "start-fuel" position. Screw (5) is used to adjust maximum fuel delivery.

START-FUEL. The "start-fuel" adjusting screw (3–Fig. M1-12) in Version I governor is eccentric. One turn changes adjustment setting from minimum to maximum. If screw is turned too far in or out, governor lever may bind against front cover or fuel pump which could result in engine overspeed. Be sure pump control rack moves freely after adjustment.

CAUTION: DO NOT adjust "start-fuel" setting with engine running.

To adjust "start-fuel", remove crankshaft pulley. Remove lower cover plate, camshaft cover (Version III only) and top plug from timing gear cover. Move throttle to maximum speed position. Use a depth micrometer through plug opening in gear cover (Fig. M1-15) to measure distance from end of pump rack (3) to surface of front cover. The distance should be 11.0-11.4 mm (0.433-0.449 inch) on D302-1, 7.0-7.4 mm (0.276-0.291 inch) on D202-2 or 6.8-7.2 mm (0.268-0.283 inch) on all other engines. Turn adjusting screw (3–Fig. M1-12, M1-13 or M1-14) to obtain specified dimension. Tighten adjusting screw locknut to secure adjustment.

STOP-LIMIT. The stop-limit adjustment provides a mechanical stop to prevent injection pump control rack from bottoming in pump when control linkage is moved to shut-off position. The adjusting screw (4–Fig. M1-12, M1-13 or M1-14) is located on timing gear cover just below the lower cover plate.

CAUTION: Turning stop-limit adjusting screw in too far will interfere with governor weight operation and result in engine overspeed. DO NOT perform stop-limit adjustment with engine running.

To adjust stop-limit, place throttle lever in shut-off position. Back out adjusting screw several turns. Using a depth micrometer (5–Fig. M1-15) through plug opening at top of timing gear cover, measure distance from surface of gear cover to end of control rack (3) with rack bottomed in pump. Subtract 0.5 mm (0.020 inch) from this reading and adjust micrometer to this dimension. Reposition depth micrometer (with adjusted setting) through plug opening, then turn stop-limit adjusting screw in until control rack just starts to lift depth micrometer away from cover. Tighten adjusting screw locknut at this position.

THROTTLE LOCK (VERSION I and II). The throttle lock adjusting screw (5–Fig. M1-12 or M1-13) can be used as a low speed adjustment for a dual speed application. The adjusting screw, if turned all the way in, will also lock the internal governor lever against the high speed screw eccentric. The engine will then run at maximum governed speed with no way to slow it down. The screw is normally left "backed out" as with either situation just described, use of the throttle lever to control engine speed or to shut-off engine will be eliminated.

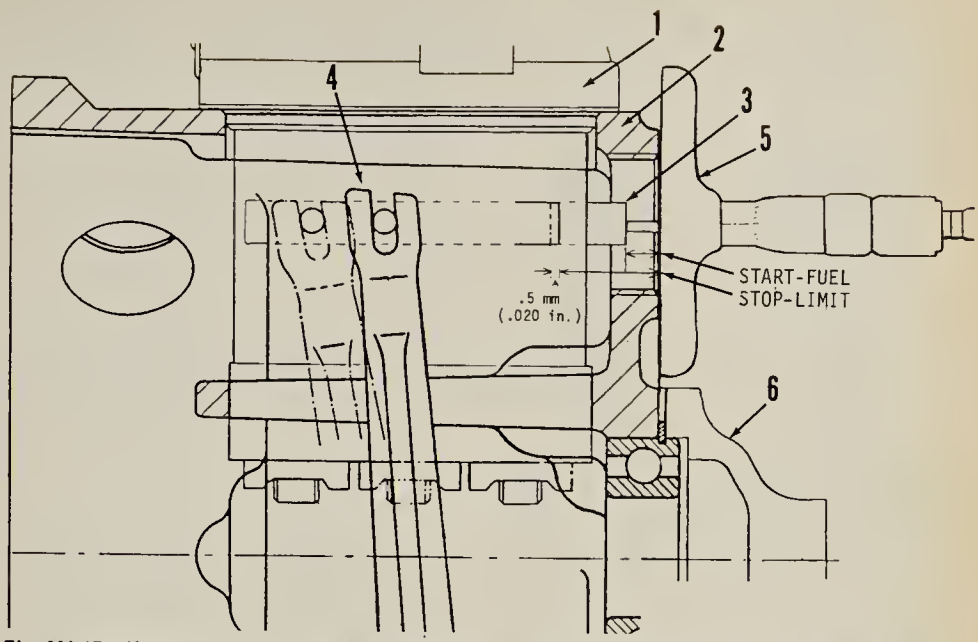


Fig. M1-15—Use a depth micrometer through plug hole at top of timing gear cover when adjusting "start-fuel" and "stop limit" settings. Refer to text.

1. Fuel injection pump
2. Timing gear cover
3. Pump control rack
4. Governor lever
5. Depth micrometer
6. Camshaft cover

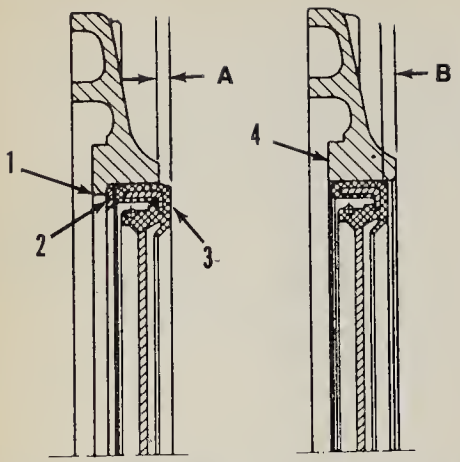
MAXIMUM FUEL DELIVERY (VERSION III). The maximum fuel delivery adjusting screw (5–Fig. M1-14) is used to set maximum full load horsepower with Version III governors. The screw, located on the camshaft cover, is not interchangeable with Version I and II governors. A dynamometer is required to properly adjust full load horsepower setting. DO NOT attempt adjustment without a dynamometer as engine damage may result from overfueling. Turning screw in will decrease maximum fuel output and turning screw out will increase fuel delivery.

CRANKSHAFT AND BEARINGS

To remove camshaft, first remove oil pan, cylinder heads, pistons and connecting rods, timing gear cover assembly, crankshaft gear (D302-1 engine), governor, oil pump, flywheel and flywheel housing. Mark position of crankshaft counterweights (D302-1 engine), then remove counterweights. Remove crankcase rear cover. On D302-1 engine, withdraw crankshaft through rear opening in crankcase. On all other engines, remove main bearing caps (noting location numbers on caps), then lift out crankshaft.

On all engines, standard diameter of crankshaft main journals is 64.951-64.970 mm (2.5571-2.5578 inches) and minimum allowable diameter is 64.940 mm (2.5567 inches). Crankpin standard diameter is 57.951-57.970 mm (2.2815-2.2823 inches) with a wear limit of 57.940 mm (2.2811 inches). Recommended main bearing clearance is 0.07-0.12 mm (0.0028-0.0047 inch) for D302-1 engine. For all other engines, main bearing clearance should be 0.08-0.11 mm (0.0031-0.0043 inch) and clearance for rear thrust bearing should be 0.09-0.12 mm (0.0035-0.0047 inch). Rod bearing clearance should be 0.07-0.10 mm (0.0028-0.0039 inch) for all engines. Main and rod bearings should be renewed if third layer of bearing material is worn off which is indicated by shiny bronze contact patterns on bearing surface. Main bearings are a press fit on D302-1 engine. Use tool M1016 (or equivalent) to remove and install bearings. Bearings are available in 0.20, 0.50, 0.75 and 1.0 mm (0.008, 0.020, 0.030 and 0.040 inch) undersizes.

On D302-1 engine, crankshaft end clearance is controlled by thrust washers at gear end of shaft. Washer thickness when new is 2.98-3.00 mm (0.117-0.118 inch) and minimum allowable thickness is 2.95 mm (0.116 inch). Recommended end clearance is 0.10-0.22 mm (0.004-0.009 inch). When installing thrust washers, be sure oil



M1-16—Crankshaft rear oil seal may be installed offset (A or B) in crankcase rear cover to obtain contact with unworn portion of crankshaft flange. Refer to text.

1. Cover with flange
2. Shim
3. Oil seal
4. Cover without flange

grooves in rear washer face web of crankshaft gear and grooves in front washer face crankshaft gear.

On all engines except D302-1, crankshaft end clearance is controlled by the flanged rear main bearing. Desired end clearance is 0.08-0.23 mm (0.003-0.009 inch). Thrust bearing is available in 0.10, 0.25 and 0.50 mm (0.004, 0.010 and 0.020 inch) oversize widths as well as an optional 1.0 mm (0.040 inch) oversize width on a limited supply basis.

To reinstall crankshaft, reverse the removal procedure while observing the following points. Make certain bearings are properly positioned on locating pins. Tighten main bearing cap screws to 130-140 N·m (96-103 ft.-lbs.). On D302-1 engine, the crankshaft gear can be installed in only one position with all four bolt holes aligned. Tighten gear mounting bolts to 30-40 N·m (22-29 ft.-lbs.). On all other engines, crankshaft gear is positioned on crankshaft with a locating pin. The gear is a shrink fit and must be heated to 220°C (425°F) prior to installation. On all engines, backlash between crankshaft gear and camshaft gear should be 0.11-0.27 mm (0.005-0.010 inch). Be sure "O" mark on crankshaft gear is aligned with "O-O" marks on camshaft gear. On D302-1 engine, the "1" mark on crankshaft gear must also be aligned with the two chamfered teeth located on back side of counterweight gear. DO NOT use scribe mark on front of gear for timing purposes. Renew crankshaft front and rear oil seals as outlined in OIL SEALS section. Tighten flywheel mounting cap screws to 120-125 N·m (89-92 ft.-lbs.), flywheel housing cap screws to 60-65 N·m (44-48 ft.-lbs.) and crankcase rear cover screws to 20-25 N·m (15-18 ft.-lbs.).

OIL SEALS

Crankshaft front oil seal is a rope type seal located in the timing gear cover. Renewal is obvious after removing front pulley and hub. Apply grease to seal surface prior to reassembly.

Crankshaft rear oil seal is a lip type seal located in the crankcase rear cover. If a groove is worn into crankshaft flange at seal location, seal may be installed offset to provide a new sealing surface. If rear cover has an inner flange (1—Fig. M1-16), install a shim (part number 6.000.0.340.004.4) between flange and new seal (3) to offset seal outward (A). If rear cover does not have a flange (4), install seal offset 2 mm (0.080 inch) inward (B) to obtain new seal contact surface. Apply grease to seal lip and crankshaft flange prior to reassembly.

MWM DIESEL

Model	No. Cyls.	Bore	Stroke	Displ.
D226-2	2	105 mm (4.13 in.)	120 mm (4.72 in.)	2078 cc (127 cu. in.)
D327-2	2	100 mm (3.94 in.)	120 mm (4.72 in.)	1885 cc (115 cu. in.)

The MWM (Murphy) engines in this section are four-stroke, direct injection diesels with vertical cylinders. D226-2 engine is liquid-cooled and D327-2 engine is air-cooled. Crankshaft rotation is counterclockwise viewed from flywheel end on all engines.

MAINTENANCE

LUBRICATION

Engine crankcase oil must be good quality oil meeting API service classification CC/SF, DC/SF, CC or CD. Use of multigrade oil is approved but oil must meet API classification CD/SF or CD. If sulfur content in the fuel exceeds 0.5 percent a CD or CD/SF oil must be used.

If ambient temperature is permanently below 0°C (32°F), SAE 10W-30 or 5W-20 oil is preferred but SAE 10W may also be used. If temperature varies between minus 10°C (14°F) and 10°C (50°F), SAE 20W-20 oil preferred but 15W-40 may also be used. If temperature is between 0°C (32°F) and 30°C (85°F), SAE 30 oil is recommended but 15W-40 may also be used. If temperature remains above 30°C (85°F), SAE 40 oil is recommended.

NOTE: Use the same oil in the injection pump as required for engine crankcase.

Recommended oil change interval is every 250 hours of operation or every six months, whichever occurs first. The oil filter should also be renewed at this time. Manufacturer recommends using only genuine MWM Diesel replacement oil filter.

Standard crankcase capacity is 5.2 liters (5.5 quarts) for D226-2 engine and 4.7 liters (5.0 quarts) for D327-2 engine.

The Robert Bosch injection pump and governor assembly is lubricated with oil. The pump oil level should be checked at the oil level plug every 125 hours of operation. Due to normal fuel leakage past the pump plungers, oil level will increase during operation and must be drained off at the level check plug. On some continuous load applications, fuel leakage may be higher than normal and oil level check/drain interval may have to be lower than 125 hours. Manufacturer recommends renewing injection pump lubricating oil after every 750 hours of operation. Use same oil as recommended for engine crankcase.

FUEL SYSTEM

FUEL FILTER AND BLEEDING. The fuel filter should be renewed after every 1000 hours of operation or sooner if loss of engine power is evident. Note that there is also a filter screen located in the inlet section of the fuel feed pump which may become plugged. If engine fails to operate properly after renewing the fuel filter, remove and clean feed pump filter screen.

Whenever fuel filter is serviced or fuel lines are disconnected, air must be bled from the fuel system. Loosen bleed screw at fuel filter housing. Actuate fuel feed pump priming lever until air-free fuel flows from bleeder, then retighten bleed screw. Loosen bleed screw at top, rear of fuel injection pump housing. Operate feed pump priming lever until air is purged from pump, then retighten bleed screw. If engine fails to start at this point, loosen high pressure fuel line fittings at the injectors. Place pump controls in "run" position, then crank engine until fuel is discharged at loosened fittings. Retighten fittings and start engine.

ENGINE SPEED ADJUSTMENT. Before attempting engine speed adjustments, the governor identification number (stamped on tag located on governor housing) must be known. Two governors which may be used on these engines are as follows: EP/RSV325..1500 A2B 550DR governor regulates speed from a minimum of 650 rpm to a maximum of 3000 rpm with an average speed droop of 5-7 percent. The EP/RSV300...1000 A7B 505DR governor regulates speed from a minimum of 600 rpm to a maximum of 2000 rpm with an average speed droop of 2-3 percent.

NOTE: Changing the maximum speed setting may result in a change in speed droop, governor instability, power or smoke level. This will require additional adjustments which must be made with the use of a pump test bench.

To increase maximum speed setting, back out the throttle lever stop screw. This will also decrease droop. To decrease maximum speed setting, turn throttle lever stop screw in. This will also increase speed droop.

If a surge develops, if droop is excessive or if desired maximum rpm cannot be obtained, the main spring screw (Fig. M2-1) must be adjusted as follows:

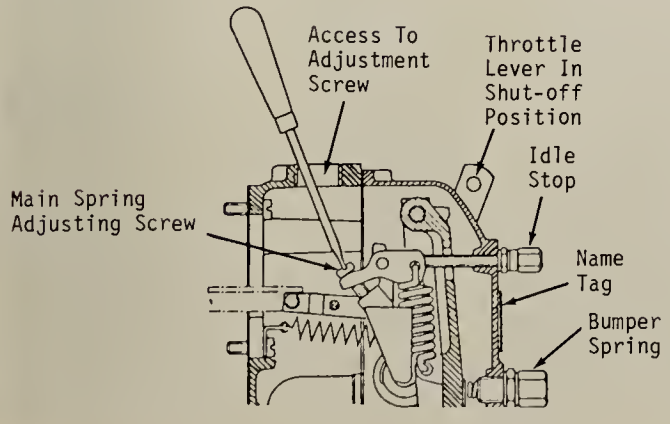


Fig. M2-1—View of governor control adjustment points.

INJECTION TIMING			
Engine	Pump Gear Equipped With Timing Device	Rpm Range	Timing Degrees Before TDC
D226	No	1500-1800	28
D226	No	1801-2300	30
D226	No	2301-2500	34
D226	No	3000	36
D226	No	3300	39
D226	Yes	650-3000	28
D327	No	1500-1800	28
D327	No	1801-2400	30
D327	No	3000 Constant	28
D327	No*	1500-1800	25½
D327	Yes	2401-2800	24
D327	Yes	650-3000	25
D327	Yes*	650-3000	25½
* Hand Start Only.			

Fig. M2-2—Injection pump timing specification table.

Remove oil filler plug or breather from top of governor housing. Back out the idle stop screw and bumper spring screw. Place throttle lever in shut-off position. Turn main spring adjusting screw clockwise until it bottoms. On A2B governors, turn screw back out 2 turns. On A7B governors, turn screw back out 2 turns for 1000-1200 rpm setting, 3 turns for 1200-1600 rpm setting or 4 turns for 1600-2000 rpm setting.

After main spring screw is adjusted, start engine and adjust idle stop screw until engine speed is 50 rpm below desired idle speed. Adjust bumper spring screw until desired idle speed is obtained. Move throttle against maximum speed stop screw (be careful not to overspeed engine), then turn stop screw until desired maximum speed is obtained.

INJECTION PUMP TIMING. To check injection pump timing, it is first necessary to establish an accurate top dead center for number 1 piston as follows: Remove rocker arm cover. Rotate crankshaft clockwise until the intake valve opens about 5-6 mm (¼ inch), then install special tool M2021 on rocker arm bracket to hold intake valve in the opened position. Fabricate a reference timing pointer and attach to front cover over the crankshaft pulley. Rotate crankshaft counterclockwise until piston just contacts the intake valve and scribe a reference mark on front pulley in line with the timing pointer. Then, rotate crankshaft clockwise until piston just contacts intake valve and scribe a second reference mark on pulley in line with timing pointer. Select a timing decal from degree decal set number M2010 that matches diameter of pulley. Position the decal equally between the two reference marks on the pulley. Remove special tool M2021 from intake valve.

Remove number 1 injector fuel line from pump and install a drip tube in its place. Connect a nozzle tester pump to injection pump inlet using line kit number M2020. Move the pump "run/stop" control lever to the midrange position. Note that injection timing will be retarded about 9° when control lever is in "run" position. If control lever is in "stop" position, port closure (beginning of injection) will not occur. Rotate crankshaft counterclockwise until timing pointer is at approximately 40° BTDC. Pump the nozzle tester handle until air-free fuel flows from drip tube. Actuate tester pump to maintain a flow from drip tube and rotate crankshaft slowly clockwise until fuel flow just stops. At this point beginning of injection occurs and timing pointer should be aligned with specified degree mark on decal (within ½ degree) as listed in table shown in Fig. M2-2.

If necessary, pump timing may be adjusted as follows: Injection pump may be shifted in its slotted mounting holes for approximately 7° of adjustment. Moving top of pump towards the engine will advance the timing. The cam gear to pump drive gear mounting holes are also slotted to allow approximately 26° of pump timing adjustment. To adjust drive gear, engine front cover must first be removed. Move crankshaft to the specified static timing degrees position and secure "run/stop" lever in midrange position. Loosen cap screws securing camshaft gear to pump drive gear, then rotate injection pump shaft counterclockwise until drive gear cap screws bottom in the slots. While actuating nozzle test pump so fuel flows from drip tube, slowly rotate pump shaft clockwise until fuel flow just stops. At this point, tighten drive gear mounting screws to 55-60 N·m (41-44 ft.-lbs.) for M8-12.9 screws or 30-35 N·M (23-25 ft.-lbs.) for M8-10.9 screws. Recheck port closure timing and, if necessary, make final adjustments by rotating pump in slotted mounting holes.

Relieve pressure in nozzle tester hose to pump, then disconnect hose. Reconnect fuel inlet line and number 1 injector line to pump. If crankshaft front hub bolts or flywheel bolts were used to rotate crankshaft, be sure to check torque on these bolts and retighten to specifications if necessary.

REPAIRS

TIGHTENING TORQUES

Refer to the following appropriate table for special tightening torques. Torque values marked with asterisk* apply to engines with 9 digit engine serial numbers (small crank engines). All fasteners are metric.

Model D226-2

Camshaft gear
- Durlok M8-12.9 ..... 55-60 N·m (41-44 ft.-lbs.)
- M8-10.9* ..... 30-35 N·m (23-25 ft.-lbs.)

Connecting rod ..... 95-100 N·m (70-74 ft.-lbs.)

Crankshaft counterweight* ..... 140-150 N·m (104-110 ft.-lbs.)

Cranshaft hub
- M16-10.9 ..... 285-295 N·m (211-217 ft.-lbs.)
- M16-12.9 ..... 345-355 N·m (255-261 ft.-lbs.)
- M12-10.9* ..... 120-125 N·m (89-92 ft.-lbs.)
- M12-12.9* ..... 145-150 N·m (107-110 ft.-lbs.)

Cylinder head
- M14-12.9 ..... 200-210 N·m (148-154 ft.-lbs.)
- M14-10.9* ..... 170-175 N·m (126-129 ft.-lbs.)

Flywheel
- M16-10.9 ..... 285-295 N·m (211-217 ft.-lbs.)
- M16-12.9 ..... 345-355 N·m (255-261 ft.-lbs.)
- M12-10.9* ..... 120-125 N·m (89-92 ft.-lbs.)
- M12-12.9* ..... 145-150 N·m (107-110 ft.-lbs.)

Model D226-2 (Cont.)

Injector ..... 10-15 N·m (8-11 ft.-lbs.)
Injection pump gear ..... 60-70 N·m (45-71 ft.-lbs.)
Main bearing cap
M14-10.9 ..... 160-170 N·m (118-125 ft.-lbs.)
M14-10.9* ..... 130-140 N·m (96-103 ft.-lbs.)
Oil Pan ..... 20-25 N·m (15-18 ft.-lbs.)
Oil pump ..... 30-40 N·m (23-29 ft.-lbs.)
Rocker arm bracket ..... 35-40 N·m (23-29 ft.-lbs.)

Model D327-2

Camshaft gear
Durlock M8-12.9 ..... 60-70 N·m (45-51 ft.-lbs.)
M8-10.9* ..... 30-35 N·m (23-25 ft.-lbs.)
Connecting rod
M12-12.9 ..... 95-100 N·m (70-73 ft.-lbs.)
M12-10.9* ..... 75-80 N·m (56-59 ft.-lbs.)
Crankshaft counterweight* ..... 140-150 N·m (104-110 ft.-lbs.)
Crankshaft hub
M16-10.9 ..... 285-295 N·m (211-217 ft.-lbs.)
M12-10.9* ..... 120-125 N·m (89-92 ft.-lbs.)
M12-12.9* ..... 150-155 N·m (111-114 ft.-lbs.)
Cylinder head ..... 50-55 N·m (37-40 ft.-lbs.)
Flywheel
M16-10.9 ..... 285-295 N·m (211-217 ft.-lbs.)
M12-10.9* ..... 120-125 N·m (89-92 ft.-lbs.)
M12-12.9* ..... 150-155 N·m (111-114 ft.-lbs.)
Injector ..... 10-15 N·m (8-11 ft.-lbs.)
Injection pump gear ..... 60-70 N·m (45-51 ft.-lbs.)
Main bearing caps
M14-10.9 ..... 160-170 N·m (118-125 ft.-lbs.)
M14-10.9* ..... 130-140 N·m (96-103 ft.-lbs.)
Oil pan ..... 20-25 N·m (15-18 ft.-lbs.)
Oil pump ..... 30-40 N·m (23-29 ft.-lbs.)
Rocker arm bracket ..... 35-40 N·m (26-29 ft.-lbs.)

COMPRESSION PRESSURE

Compression pressure may be checked to establish relative condition of engine before proceeding with engine disassembly. To check compression pressure, remove both injectors and install test adapter M3002 in one of the injector bores in cylinder head. Crank engine 3 to 5 revolutions. With engine cold, normal compression pressure at cranking speed is 2200-2700 kPa (320-390 psi) for D226-2 engine and 2500-2700 kPa (363-390 psi) for D327-2 engine. Compression pressure should not be less than 2000 kPa (290 psi) for D226-2 engine or 2200 kPa (320 psi) for D327-2 engine. On all engines, pressure difference between cylinders should not vary more than 300 kPa (43 psi). Some causes of low compression pressure are: valves leaking, piston rings worn, cylinder scored or clearance between piston and cylinder head too large.

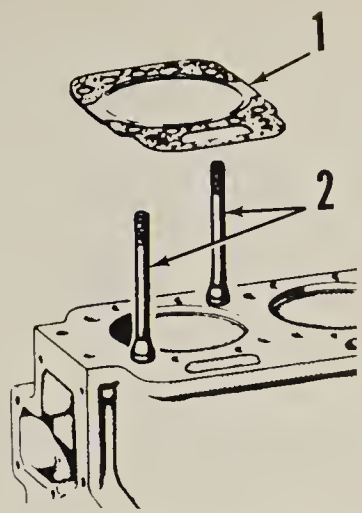


Fig. M2-3—Use guides studs (2) to align cylinder heads and gaskets (1) when reassembling.

VALVE ADJUSTMENT

Valve clearance is adjusted with engine cold. Remove rocker arm covers, then turn crankshaft until piston for cylinder being adjusted is at top dead center on compression stroke (both valves closed). Loosen locknut and turn rocker arm adjusting screw until a 0.20 mm (0.008 inch) feeler gage can be inserted between rocker arm and valve stem end. Tighten adjusting screw locknut and recheck clearance. Repeat procedure for the other cylinder.

CYLINDER HEAD

An individual cylinder head is used for each cylinder. Be sure to identify heads before removal so they can be reinstalled in their original location.

Whenever piston, cylinder, connecting rod, crankshaft or crankcase have been renewed, piston height in cylinder should be checked to ensure adequate clearance between top of piston and cylinder head before reinstalling cylinder head. On D327-2 engine, install spacer tubes and tighten nuts on cylinder studs to hold cylinders firmly against crankcase surface. With piston at top dead center, use a dial gage to measure distance from top of piston to flat surface of cylinder barrel on D327-2 engine. On D226-2 engine with 9 digit engine number, piston should be 0.28-0.60 mm (0.0110-0.0236 inch) below surface of crankcase. On D226-2 engine with 10 digit engine number, piston should be 0.25-0.57 mm (0.010-0.022 inch) above surface of crankcase. On D327-2 engine, piston clearance should be 4.57-4.67 mm (0.180-0.184 inch). Change thickness of shims between bottom of cylinder and crankcase mounting surface to obtain specified piston height on D327-2 engine.

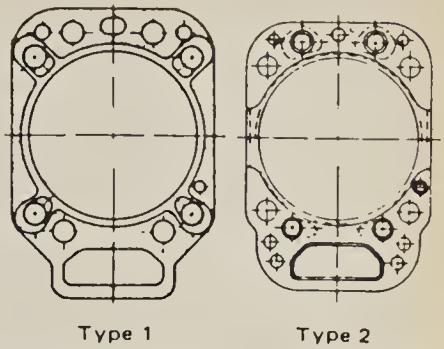


Fig. M2-4—Two different types of head gaskets are available. Type 1 is used on big crank engines and Type 2 is used on small crank engine. Refer to text.

To reinstall cylinder head on D226-2 engine, proceed as follows: Install two alignment studs M1006 (or equivalent) diagonally from each other in two cylinder head bolt holes (Fig. M2-3). Place cylinder head gaskets over guide studs.

NOTE: Make certain correct gaskets are used. Type 1 gasket (Fig. M2-4) is 1.6 mm (0.063 inch) thick, is brown or white in color and is used on 10 digit engine number (big crank engines. Type 2 gasket is 0.9 mm (0.035 inch) thick, is grey in color and is used on 9 digit engine number (small crank) engines.

Assemble cylinder heads over alignment studs and install two bolts (with threads oiled) finger tight. Use a straightedge to align cylinder heads at intake and exhaust port machined surfaces. Remove alignment studs and install the other two bolts. Tighten all bolts evenly in steps using a crosswise pattern to 170-175 N·m (126-129 ft.-lbs.) for 9 digit identification number engines or 200-210 N·m (148-154 ft.-lbs.) for 10 digit identification number engines. Run

engine for about one hour, then stop and allow to cool. With engine cold, loosen head bolts ¼ turn and retorque to specified setting. Readjust valve clearance.

To reinstall cylinder head on D327-2 engine, proceed as follows: Assemble cylinder heads with new gaskets onto cylinder studs. Lubricate bottom of stud nuts and threads of nuts and studs with Molykote "G-n" paste or equivalent. Use a straightedge to align cylinder heads at intake and exhaust port machined surfaces. Tighten stud nuts evenly in small increments using a crosswise tightening pattern to 45-50 N·m (34-36 ft.-lbs.). Operate engine for about ½ hour, then stop and allow to cool. Loosen stud nuts ¼ turn, then retighten in steps using the crosswise pattern to 50-55 N·m (37-40 ft.-lbs.). Recheck valve clearance.

VALVE SYSTEM

Intake and exhaust valve face angle should be 45½° and valve seat angle should be 45°. Desired valve seat width is 1.35-1.80 mm (0.053-0.070 inch) and maximum width is 2.5 mm (0.10 inch) for both valves. With valves installed, the valve heads should be recessed 1.03-1.42 mm (0.040-0.055 inch) below combustion surface of cylinder head. Valve seat inserts should be renewed if valve recession exceeds 1.80 mm (0.070 inch).

Valve seat inserts are interference fit in cylinder head. Standard cylinder head counterbore diameter is 43.030-43.046 mm (1.6941-1.6947 inches) for intake and 38.960-38.976 mm (1.5338-1.5344 inches) for exhaust. If worn or damaged, insert counterbores may be machined oversize 0.20 mm (0.0078 inch) for installation of oversize inserts. Cylinder head should be heated to about 200°C (400°F) prior to installing new inserts. After head cools, regrind valve seats.

Valve stem diameter for both valves is 8.952-8.970 mm (0.3525-0.3531 inch) with a wear limit of 8.949 mm (0.3523 inch). Valve guide inner diameter should be 9.013-9.028 mm (0.3549-0.3554 inch) with a wear limit of 9.060 mm (0.3567 inch). Valve guides are a press fit in cylinder head. If bore in cylinder head is worn or damaged, bore may be machined for installation of guides with 0.1 or 0.2 mm (0.004 or 0.008 inch) oversize outside diameter. After installation of new guides, valve seats must be reground.

Rocker arm bracket shaft diameter is 15.966-15.984 mm (0.6285-0.6293 inch) with a wear limit of 15.950 mm (0.6280 inch). Rocker arm bushing inner diameter should be 16.000-16.018 mm (0.6299-0.6306 inch) and maximum allowable diameter is 16.030 mm (0.6311 inch).

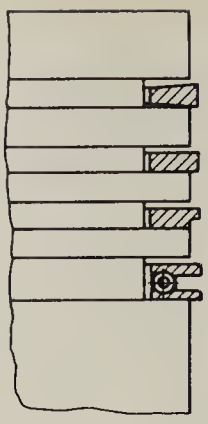


Fig. M2-5—Cross-sectional view showing correct installation of piston rings.

INJECTOR

REMOVE AND REINSTALL. To remove injector, disconnect fuel lines and immediately plug all openings to prevent entry of dirt. Remove mounting bracket nuts and withdraw injector and seal washer.

To reinstall, reverse the removal procedure using a new nozzle seal washer. Tighten mounting bracket nuts to 10-15 N·m (8-11 ft.-lbs.).

TESTING. A special nozzle test pump is required to check injector operation. Injection should be checked for specified opening pressure, nozzle leakage and correct spray pattern.

WARNING: Fuel leaves the injector nozzle with sufficient force to penetrate the skin. When testing, keep yourself clear of nozzle spray.

Connect injector to nozzle test pump, then operate tester lever several quick strokes to purge air from injector and to make sure nozzle valve is not stuck, then operate tester lever slowly while observing tester gage. Nozzle opening pressure should be 18000-18500 kPa (2610-2680 psi) for all engines. Opening pressure may be adjusted by changing thickness of spring adjusting shims. Changing shim thickness 0.1 mm (0.004 inch) will change pressure about 1000 kPa (145 psi).

To check nozzle for leakage, operate tester lever slowly to maintain pressure at 2000 kPa (300 psi) below opening pressure and observe nozzle tip for leakage. If a drop falls from nozzle tip within a 10 second period, nozzle valve is not seating and injector should be overhauled or renewed. During this test, be careful not to confuse fuel leaking from leak-off fitting at top of injector with leakage at nozzle tip.

To check spray pattern, operate the tester lever several quick strokes (about one stroke per second). All four nozzle spray holes must be open. Spray should be uniform and well atomized and nozzle should produce a "chatter" sound when operating properly.

INJECTION PUMP

A Robert Bosch fuel injection pump is used on all engines. The pump contains its own oil supply for lubrication of pump camshaft and governor components. Refer to MAINTENANCE section for lubrication details.

To remove injection pump, first disconnect fuel lines and immediately plug all openings. Disconnect speed control and engine stop linkage from pump. Remove crankshaft pulley and timing gear cover. Remove camshaft drive gear and injection pump drive gear or timing device (if so equipped) using suitable gear puller such as tool number M2024. Remove pump mounting nuts and remove injection pump.

It is recommended that injection pump be tested and overhauled only by a shop qualified in diesel fuel injection repair.

When reinstalling pump, be sure timing marks on pump drive gear and the drive gear on the camshaft are aligned. Tighten injection pump gear retaining nut to 60-70 N·m (45-51 ft.-lbs.). Adjust injection pump timing as previously outlined in MAINTENANCE section.

PISTON, PISTON PIN AND RINGS

The piston is equipped with a keystone type top ring, a rectangular second ring, notched third ring and an oil control ring at the bottom. Refer to Fig. M2-5. Piston standard diameter for D226-2 engine is 104.650-104.680 mm (4.1201-4.1212 inches) and minimum allowable diameter is 104.500 mm (4.1142 inches). Piston standard diameter for D327-2 engine is 99.450-99.470 mm (3.9154-3.9161 inches) and minimum allowable diameter is 99.400 mm (3.9134 inches).

On all engines, ring groove width should be 2.060-2.080 mm for second and third ring grooves with a wear limit of 2.120 mm (0.083 inch). Width of oil control ring groove should be 4.040-4.060 mm (0.1590-0.1598 inch) and maximum width is 4.100 mm (0.1614 inch). Top ring groove is keystone type and a special tool is required to check ring groove wear. Maximum allowable side clearance between rings and grooves is 0.20 mm (0.008 inch) for second and third rings and 0.15 mm (0.006 inch) for oil control ring.

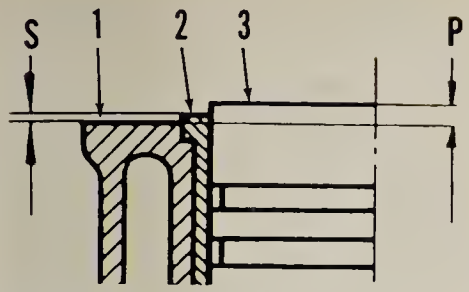


Fig. M2-5A—When cylinder liner is properly installed on D226-2 engine, top of liner must project above surface of crankcase. Refer to text for specified dimensions (S and P).

1. Crankcase
2. Cylinder liner
3. Piston

Piston ring end gap is measured with ring positioned squarely in cylinder bore. Desired end gap is 0.20-0.25 mm (0.008-0.010 inch) for all rings and maximum allowable end gap is 2.0 mm (0.079 inch).

The full floating piston pin is retained in the piston by two snap rings. Piston pin diameter is 34.994-35.000 mm (1.3777-1.3779 inches) for all engines with 10 digit engine numbers with a wear limit of 34.990 mm (1.3776 inches). Pin diameter for engines with 9 digit engine number is 31.994-32.000 mm (1.2596-1.2598 inches) with a minimum allowable diameter of 31.990 mm (1.2595 inches). Inner diameter of pin bore in piston should be 35.003-35.009 mm (1.3781-1.3783 inches) with a wear limit of 35.014 mm (1.3785 inches) for engines with 10 digit number. Piston pin bore for engines with 9 digit number should be 32.003-32.009 mm (1.2600-1.2602 inches) with a wear limit of 32.014 mm (1.2604 inches).

When reassembling, be sure third ring is installed notched side down. Be sure ring end gaps are staggered at 180° intervals around piston. Make certain arrow on piston crown is pointing towards flywheel end of engine when reinstalling piston. Check piston height in cylinder as outlined in CYLINDER HEAD section.

CYLINDER

Model D226-2 Engine

The D226-2 engine is equipped with renewable, dry type cylinder liners. Replacement liners are available semifinished which are a press fit in cylinder bores, or prefinished which are a slip fit in cylinder bores. The prefinished liner is available with a standard flange and a 0.50 mm (0.002 inch) oversize flange.

Cylinder liner standard diameter is 105.000-105.022 mm (4.1339-4.1347 inches) with a wear limit of 105.250 mm (4.1437 inches). If excessively worn or damaged, liners may be rebored for installation of 0.5 mm (0.020 inch) oversize pistons and rings.

Use special tool M1026 (or equivalent) to remove and install liners. Be sure to thoroughly clean cylinder bore and outside of liner before installing. When installing press fit liners, apply a light coat of oil to top of cylinder bore and bottom of liner before pressing into crankcase. After installation, top of liner flange (2—Fig. M2-5A) must project a distance (S) above surface of crankcase of 0.02-0.07 mm (0.0008-0.0027 inch) for engines with 9 digit engine numbers or 0.05-0.10 mm (0.002-0.004 inch) for engines with 10 digit numbers. If projection is excessive, remove liner and check crankcase counterbore for dirt or other obstructions. If projection is less than specified, install liner with an oversize flange.

After pistons are installed, piston height (P) in sleeve should be measured to ensure assembly is correct. On engines with 9 digit number, top of piston should be 0.28-0.60 mm (0.0110-0.0236 inch) below surface of crankcase. On engines with 10 digit number, top of piston should be 0.25-0.57 mm (0.010-0.022 inch) above surface of crankcase.

Model D327-2 Engine

The D327-2 engine is equipped with removable, individual, cast iron cylinder barrels. Standard cylinder bore is 100.000-100.022 mm (3.9370-3.9378 inches) with a wear limit of 100.250 mm (3.9468 inches). If cylinders are excessively worn or damaged, they may be rebored for installation of 0.5 or 1.0 mm (0.020 or 0.040 inch) oversize pistons and rings.

After installing new cylinder barrels, check piston height in cylinder with piston at top dead center. Install two pipe spacers diagonally on cylinder studs and tighten two stud nuts to seat cylinder firmly against crankcase. The distance from the flat surface of cylinder to top of piston must be 4.57-4.67 mm (0.180-0.184 inch). Piston compression height is adjusted using shims between bottom of cylinder and mounting surface of crankcase.

CONNECTING ROD

The connecting rod uses a bushing in the small end. Bushing inside diameter should be 35.030-35.080 mm (1.3791-1.3811 inches) on engines with 10 digit engine number with a wear limit of 35.150 mm (1.3838 inches). Outside diameter of piston pin is 34.994-35.000 mm (1.3777-1.3779 inches) with a wear limit of 34.990 mm (1.3776 inches). On engines with a 9 digit engine number, bushing inside diameter should be 32.030-3.080 mm (1.2610-1.2630 inches) and maximum allowable inner diameter is 32.150 mm (1.2657 inches). Piston pin diameter is 31.994-32.000 mm (1.2596-1.2598 inches) with a wear limit of 32.990 mm (1.2595 inches). Desired operating clearance for all engines is 0.03-0.08 mm (0.0012-0.0031 inch).

A precision, insert type bearing is used in the connecting rod big end. Standard diameter of crankpin is 62.951-62.970 mm (2.4784-2.4791 inches) on engines with 10 digit number (big crank) or 57.951-57.970 mm (2.2815-2.4791 inches) on engines with 9 digit number (small crank). Desired operating clearance for crankpin in rod bearing is 0.07-0.10 mm (0.0027-0.0039 inch) for all engines. Connecting rod bearing must be renewed when the third layer of bearing material wears off which will be indicated by a shiny bronze contact pattern appearing on the bearing surface. Connecting rod side clearance between big end and crankshaft should be 0.30-0.50 mm (0.0118-0.0197 inch).

The connecting rod bearing is positioned in big end of rod with a locating pin. When assembling connecting rod and bearing, it is recommended that lower half of bearing insert be installed without bearing cap to ensure notch in bearing is indexed with pin. Then, install bearing cap and tighten screws to 95-100 N·m (70-74 ft.-lbs.) on engines with 10 digit engine number or 75-80 N·m (56-59 ft.-lbs.) on engines with 9 digit number.

TIMING GEARS AND FRONT COVER

To remove crankcase front cover, first remove engine cooling fan and crankshaft front pulley. Remove tachometer drive (if so equipped) from front cover. Remove front cover mounting screws and withdraw cover. Crankshaft oil seal is located in front cover and may be renewed at this time.

Remove gears as necessary. Use a suitable puller to remove injection pump gear or timing device. Crankshaft gear is a shrink fit. Gear must be heated to 270°C (518°F) prior to installation. Backlash between any two timing gears should be 0.12-0.28 mm (0.005-0.011 inch). Renew gears if backlash is excessive. Backlash between oil pump gear and crankshaft gear should be 0.2 mm (0.008 inch). Loosen oil pump mounting screws and move pump housing to obtain desired backlash.

When reassembling gears, align timing marks as follows: The "0" mark (1 – Fig. M2-6) on injection pump timing device or drive gear must be aligned with "0-0" marks (2) on drive gear on camshaft hub. The "0" mark on the crankshaft gear (3 – Fig. M2-7) must be aligned with "0-0" marks on camshaft gear (2). The oil pump gear (4) is installed in any position.

CAMSHAFT

The camshaft is supported at the front by a renewable bushing in crankcase front bulkhead. Center and rear camshaft journals operate directly in unbushed bores in crankcase.

To remove camshaft, first remove cylinder heads and push rods, crankshaft pulley and timing gear cover. Unbolt and remove camshaft gears. Remove camshaft retaining plate. Turn engine upside down and move cam followers away from camshaft. Carefully withdraw camshaft from crankcase. Identify location of cam followers as they are removed for use in reassembly.

Inspect camshaft and cam followers for scoring and renew if necessary. Camshaft journal diameter is 42.940-42.960 mm (1.6906-1.6913 inches) with a wear limit of 42.920 mm (1.6898 inches). Camshaft bushing bore diameter should be 43.000-43.039 mm (1.6929-1.6944 inches) and maximum allowable diameter is 43.060 mm (1.6953 inches). Center and rear crankcase bore diameter should be 43.000-43.025 mm (1.6929-1.6939 inches) with a wear limit of 43.040 mm (1.6945 inches). Desired operating clearance for camshaft journals is 0.04-0.08 mm (0.0016-0.0031 inch).

If camshaft journals or crankcase bores are excessively worn, the journals may be ground 0.30 mm (0.012 inch) undersize the crankcase center and rear bores can be rebored for installation of bushings. Machine crankcase bores to an inner diameter of 47.000-47.025 mm (1.8504-1.8513 inches), then press in new bushings. The end of rear bushing should be recessed 4 mm (0.157 inch) from rear surface of crankcase. Be sure to align hole in bushing with oil passage hole in crankcase. Inner diameter of bushings must be finish machined to match camshaft being installed (new dimension or undersize). Bushing bore should be 43.000-43.025 mm (1.6929-1.6939 inches) for new dimension camshaft or 42.700-42.725 mm (1.6811-1.6821 inches) for undersize camshaft. After installing bushings a different cover (number 6.305.0.787.0.011.4) must be installed to seal rear bore.

Cam follower outer diameter should be 17.983-17.994 mm (0.7080-0.7084 inch) and minimum allowable diameter is 17.975 mm (0.7077 inch). Crankcase bore diameter is 18.000-18.015 mm (0.7087-0.7092 inch) with a wear limit of 18.020 mm (0.7095 inch).

Camshaft end play is controlled by the retainer bracket which engages the groove in end of camshaft. Bracket thickness when new is 6.850-7.050 mm (0.2697-0.2775 inch) and minimum allowable thickness is 6.750 mm (0.2658 inch). Width of groove in camshaft should be 7.100-7.190 mm (0.2795-0.2830 inch) with a wear limit of 7.220 mm (0.2843 inch). Desired end play is 0.10-0.29 mm (0.0039-0.0114 inch).

To reinstall camshaft, reverse the removal procedure. Align timing marks on gears as outlined in TIMING GEARS AND FRONT COVER section. Tighten camshaft gear retaining screws to specified torque.

CRANKSHAFT AND BEARINGS

When removing crankshaft, note that main bearing caps are numbered for correct reassembly. If main bearing inserts will be reused, keep inserts with their respective caps so they can be reinstalled in original positions.

On engines with 10 digit engine number (big crank), standard diameter of main journals is 69.951-69.970 mm (2.7540-2.7547 inches) and minimum allowable diameter is 69.940 mm (2.7535 inches). Crankpin standard diameter is 62.951-62.970 mm (2.4784-2.4791 inches) with a wear limit of 62.940 mm (2.4780 inches).

On engines with 9 digit engine number (small crank), standard diameter of main journals is 64.951-64.970 mm (2.5572-2.5578 inches) and minimum allowable diameter is 64.940 mm (2.5567 inches). Crankpin standard diameter is 57.951-57.970 mm (2.2815-2.2822 inches) with a wear limit of 57.940 mm (2.2811 inches).

On all engines, recommended main bearing clearance is 0.08-0.11 mm (0.0031-0.0043 inch) and rod bearing clearance is 0.07-0.10 mm (0.0027-0.0039 inch). Bearing inserts must be renewed if third layer of bearing material is worn off which is indicated by shiny bronze contact patterns on bearing surface. Bearings are available in undersizes of 0.25, 0.50, 0.75 and 1.0 mm (0.010, 0.020, 0.030 and 0.040 inch) as well as standard size.

Crankshaft end play is controlled by thrust rings on each side of rear main bearing on big crank engines with 10 digit engine number. Recommended end play is 0.04-0.25 mm (0.002-0.010 inch). Thrust rings are available in standard width as well as 0.10, 0.20, 0.30 and 0.50 mm (0.004, 0.008, 0.012 and 0.020 inch) oversize widths. Make certain thrust rings are installed with grooved side facing crankshaft web and flange surfaces.

On small crank engines with 9 digit engine number, crankshaft end play is controlled by flanges on each side of rear main bearing. Recommended end play is 0.08-0.23 mm (0.003-0.009 inch) on D226-2 engine and 0.12-0.21 mm (0.005-0.008 inch) on D327-2 engine. Bearings are available in standard thrust width as well as 0.10, 0.25 and 0.50 mm (0.004-0.010 and 0.020 inch) oversize widths. An optional 1.0 mm (0.040 inch) oversize width is also available on a limited supply basis.

When reinstalling crankshaft, make certain the bearings are properly positioned on locating pins and bearing caps are reinstalled in their original positions. Tighten main bearing cap screws to specified torque. Be sure "0" mark on crankshaft gear is aligned with "0-0" marks on camshaft gear. Renew

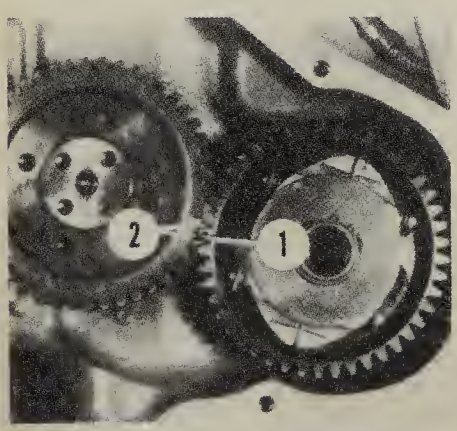


Fig. M2-6—When installing timing gears, "0" mark (1) on injection pump gear must be aligned with "0-0" marks (2) on drive gear on camshaft hub.

Fig. M2-7—View of timing gears. injection pump drive gear is mounted to rear of camshaft gear (2).

1. Injection pump gear
2. Camshaft gear
3. Crankshaft gear
4. Oil pump gear

crankshaft front and rear oil seals as outlined in OIL SEALS section.

OIL SEALS

Crankshaft front oil seal is located in timing gear cover. To renew seal, first remove crankshaft pulley and hub. Then, pry old seal out of cover being careful not to damage cover bore. Clean hub surface and polish with fine emery cloth. If wear is evident on hub surface (groove exceeding 1 mm (0.039 inch), renew hub. Apply film of grease to outer diameter of seal and seal lip. Using a suitable installing tool, press seal into cover until it bottoms against inner flange (if so equipped) or until flush with outer suface of cover. Apply grease to hub surface, then reinstall on crankshaft. Tighten mounting screws to specified torque.

Crankshaft rear oil seal is located in crankcase rear cover. If a groove is worn into crankshaft flange at original seal location, new seal may be installed offset to provide a new sealing surface. If rear cover has a flange (1 – Fig. M2-8), install a shim (part number 6.206.0.340.004.4) between flange and new seal (3) to offset seal outward (A). If rear cover does not have a flange, install seal offset 2 mm (0.080 inch) inward (B) to obtain new seal contact area. Apply grease to seal lip and crankshaft flange prior to reassembly.

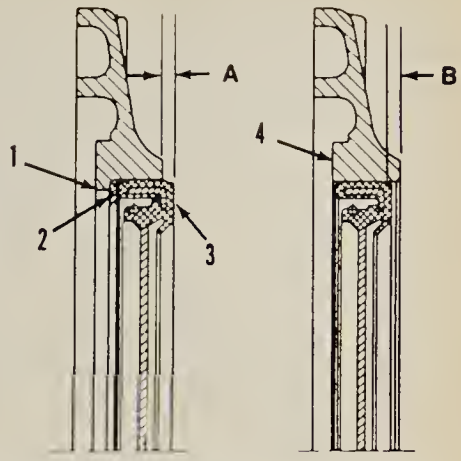


Fig. M2-8—Crankshaft rear oil seal may be installed offset (A or B) in crankcase rear cover to obtain contact with unworn portion of crankshaft flange if necessary.

1. Cover with flange
2. Shim
3. Oil seal
4. Cover without flange

ONAN

1400 73rd Avenue N.E.
Minneapolis, Minnesota 55432

Model	No. Cyls.	Bore	Stroke	Displ.
DJA	1	3¼ in. (82.55 mm)	3⅝ in. (92.08 mm)	30 cu. in. (492 cc)
DJB	2	3¼ in. (82.55 mm)	3⅝ in. (92.08 mm)	60 cu. in. (983 cc)
DJBA	2	3¼ in. (82.55 mm)	3⅝ in. (92.08 mm)	60 cu. in. (983 cc)
DJC	4	3¼ in. (82.55 mm)	3⅝ in. (92.08 mm)	120 cu. in. (1966 cc)
DJE	2	3½ in. (88.90 mm)	3⅝ in. (92.08 mm)	(70 cu. in.) (1147 cc)
RDJC	4	3¼ in. (82.55 mm)	3⅝ in. (92.08 mm)	120 cu. in. (1966 cc)
RDJE	2	3½ in. (88.90 mm)	3⅝ in. (92.08 mm)	70 cu. in. (1147 cc)
RDJEA	2	3½ in. (88.90 mm)	3⅝ in. (92.08 mm)	70 cu. in. (1147 cc)
RDJF	4	3½ in. (88.90 mm)	3⅝ in. (92.08 mm)	140 cu. in. (2294 cc)

These ONAN engines make up a family of diesel-fueled power units having many features and specifications in common. Models with an "R" prefix, such as Model RDJC, are liquid-cooled while all other models are air-cooled. All models are equipped for electric starting only, with current production engines using a 12 volt automotive type starting motor. Some earlier models of DJA engine-generator sets are exciter cranked by switching 12 volt battery current through DC windings of direct coupled generator which serves as a starter.

Maintenance and repair procedures pertain to all engines in this group with special attention directed to particular differences among models.

OPERATION

PREHEATING AND STARTING. All engines are equipped with a glow plug in each cylinder to heat the precombustion chamber and a manifold heater to heat intake air.

CAUTION: Do not use ether as a starting aid. Heat from glow plugs or manifold heater could ignite ether vapors causing an explosion resulting in severe engine damage.

If engine is cold and air temperature is 55°F (13°C) or above, energize preheat circuit for approximately 20 seconds. If air temperature is below 55°F (13°C), preheat for one minute. While holding preheat switch on, engage starting switch until engine starts. Continue to preheat until engine runs smoothly. If engine fails to start after 30 seconds of cranking, preheat for one minute more and attempt to start again. Absence of exhaust smoke during cranking indicates no fuel delivery.

NOTE: Do not energize preheat circuit longer than one minute to prevent glow plug and heater element damage. Do not apply booster voltage in excess of 12 volts to starting system as preheat circuit will be damaged.

All engines are equipped with a low oil pressure safety switch and some models may also be equipped with a high temperature safety switch. If safety switches do not close and engine fails to start, check electrical circuit for continuity and check switch controls for proper adjustment.

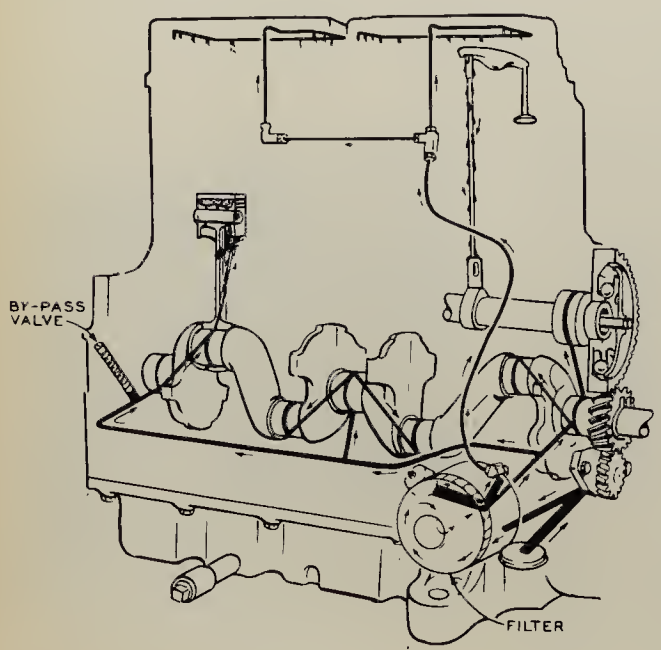


Fig. O200—View of full-pressure oil system used on all engines. Bypass valve is nonadjustable and normally opens at 25 psi (172 kPa). All models are equipped with a full-flow, spin-on type oil filter.

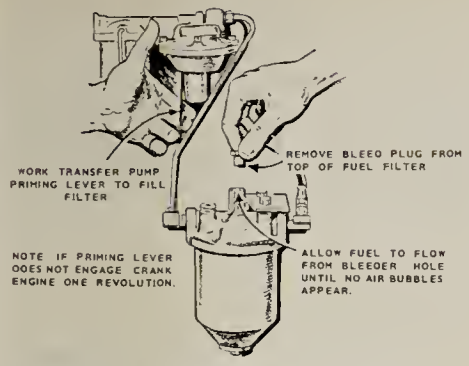

WORK TRANSFER PUMP PRIMING LEVER TO FILL FILTER
REMOVE BLEED PLUG FROM TOP OF FUEL FILTER
NOTE IF PRIMING LEVER DOES NOT ENGAGE CRANK ENGINE ONE REVOLUTION.
ALLOW FUEL TO FLOW FROM BLEEDER HOLE UNTIL NO AIR BUBBLES APPEAR.

Fig. O201 — View showing bleeding air on early model fuel system. Refer to text.

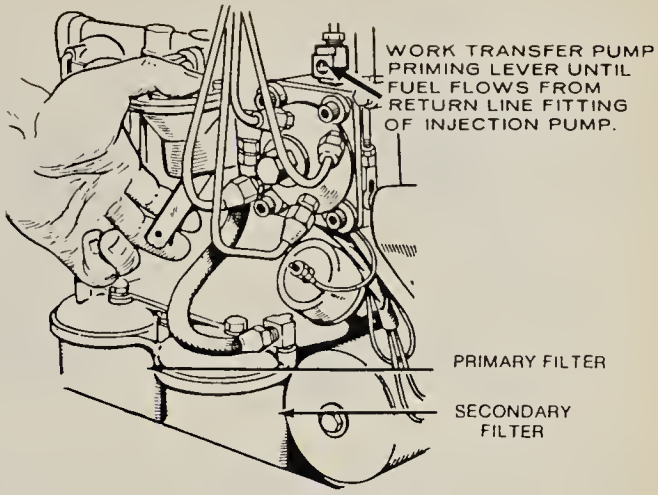

WORK TRANSFER PUMP PRIMING LEVER UNTIL FUEL FLOWS FROM RETURN LINE FITTING OF INJECTION PUMP.
PRIMARY FILTER
SECONDARY FILTER

Fig. O202 — On later models, disconnect injection pump return line to bleed air from system.

MAINTENANCE

LUBRICATION

Recommended oil for crankcase use is API service classification CD/SF or CD/SE. Recommended oil change interval is after every 100 hours of operation with filter changed simultaneously. Check oil level daily.

Crankcase capacities (with filter change) are as follows:

DJA.....3 qts. (2.8 L)
DJB, DJBA, DJE.....3.5 qts. (3.3 L)
RDJE, RDJEA.....3 qts. (2.8 L)
DJC, RDJC, RDJF.....6.5 qts. (6.1 L)

If operating temperatures fall below 0°F (+18°C), SAE 5W-30 weight oil is recommended. From 0°F (+18°C) to 32°F (0°C), use SAE 10W-30 or 10W-40. Above 32°F (0°C), SAE 30 or SAE 40 weight oil may be used.

FUEL

A good quality number 2 diesel fuel is recommended for most conditions. Number 1 diesel fuel may be used for cold weather operation or for long periods of light duty operation. All fuel must have a minimum cetane number of 45.

NOTE: It is extremely important that fuel be kept clean and free of water. Due to precise tolerances of diesel injection components, dirt and water in the system can cause severe damage to injection pump and nozzles.

FUEL FILTERS. The fuel filter system consists of a sediment bowl, located at inlet of fuel transfer pump, and primary and secondary filters, located between transfer pump and injection pump. Water and sediment should be drained periodically from sediment bowl and both filters. Manufacturer recommends renewing primary filter after every 600 hours of operation and secondary filter after every 3000 hours of operation. However, fuel filter renewal interval is more dependent upon fuel quality and cleanliness than length of service or operating conditions. If engine indicates signs of fuel starvation (loss of power or surging), renew filters regardless of hours of operation. After renewing filters, air must be bled from system as outlined in following paragraph.

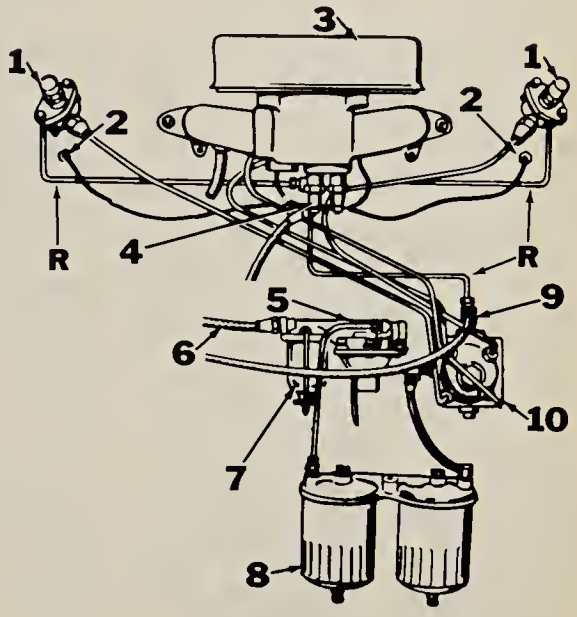


Fig. O203—View of diesel fuel system typical of late models.

1. Injection nozzles
2. Glow plugs
3. Air cleaner
4. Manifold heater
5. Fuel transfer pump
6. Fuel supply line
7. Sediment bowl
8. Fuel filters
9. Fuel return line
10. Injection pump

R. Leak-off (return) lines

BLEED FUEL SYSTEM. To bleed air from fuel system, loosen bleed plug (Fig. O201) on top of secondary fuel filter (early models) or disconnect injection pump fuel return line (Fig. O202) on late models. Then, actuate primer lever on fuel transfer pump until air-free fuel flows. Return primer lever to normal operating position after bleeding operation is completed.

NOTE: If cam which drives transfer pump is at full lift, priming lever cannot be operated. Turn crankshaft one revolution to reposition cam.

INJECTION PUMP

Late Model DJE is equipped with either a Bryce or Kiki injection pump. Model DJA is equipped with an American Bosch Model PLB injection pump while all other models are equipped with an American Bosch Model PSU injection pump. Refer to the following pump sections for injection pump timing.

BOSCH MODEL PLB. On Model DJA, injection starts at 17° BTDC which corresponds to "PC" (port closing) mark stamped on flywheel. Adjustment is made by changing the thickness of a shim pack which is fitted between pump mounting pad on crankcase and pump body mounting flange.

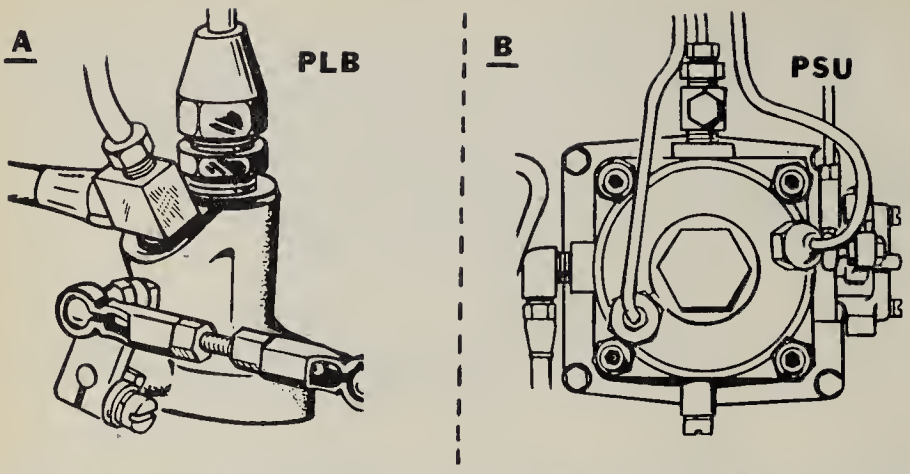


Fig. O204—American Bosch injection pumps are used on all engines except late Model DJE which is equipped with a Bryce or Kiki injection pump. Model PLB (View A) is fitted to DJA engines and Model PSU is used on all other engines.

To adjust timing, shut off fuel supply. Disconnect fuel lines and remove injection pump. Cap all connections as they are loosened to prevent entry of dirt into system. Turn crankshaft until piston is on compression stroke and "PC" flywheel mark is aligned with pointer. Using a depth micrometer, measure the distance from pump tappet to pump mounting surface of crankcase as shown in Fig. O205. Subtract 1.670 inches (42.42 mm), standard Port Closing Dimension, from the measured depth to determine shim pack thickness required. Shim pack thickness should be 0.006-0.052 inch (0.15-1.32 mm). If the calculated thickness does not fall within these limits, recheck measurement and/or check for camshaft or tappet wear or improper assembly. Shims are available in an installation shim kit which contains all necessary thicknesses.

BOSCH MODEL PSU. Models DJB, DJBA, DJC, RDJC, RDJE, RDJEA, RDJF and early Model DJE are equipped with an American Bosch Model PSU injection pump.

Injection timing for PSU pumps calls for insertion of a timing button of proper thickness between pump plunger and tappet. Refer to Fig O207. All engines are factory-timed and port closing mark appears at a point on flywheel which may be at 17°, 19° or 21° BTDC depending on production series or specification letter of a particular engine. Coding of timing button and port closing dimension are stamped on pump flange as shown in Fig. O207.

Two methods for timing injection pumps are used. If pump is renewed, use procedure number one to time new pump to engine. Second method is required if timing dimensions are unavailable or if major parts such as crankcase, crankshaft or flywheel are renewed.

METHOD I. Shut off fuel supply, disconnect all lines, unbolt and remove pump. Protect open lines from dirt and damage. Use the following formula to calculate button thickness:

EXAMPLE

Port closing dimension
(old pump).....1.109 in.
(28.168 mm)
Button thickness
(old pump) .....+0.107 in.
(2.718 mm)
Total: 1.216 in.
(30.886 mm)

Now, subtract:
Port closing dimension
(new pump) .....-1.094 in.
(27.787 mm)
Button thickness required
for new pump.....0.122 in.
(3.099 mm)

Refer to table, Fig. O208, and select button to correspond. In this example, Code 12 or M, part number 147-0190, will be correct. Install button under tappet as in Fig. O207.

NOTE: When removing tappet, be sure to hold pump drive securely to pump body to prevent pump from coming apart. Make certain metering sleeve does not drop off the plunger when plunger is removed.

Reinstall injection pump as follows: Rotate crankshaft until number 1 cylinder is on compression stroke and port clos-

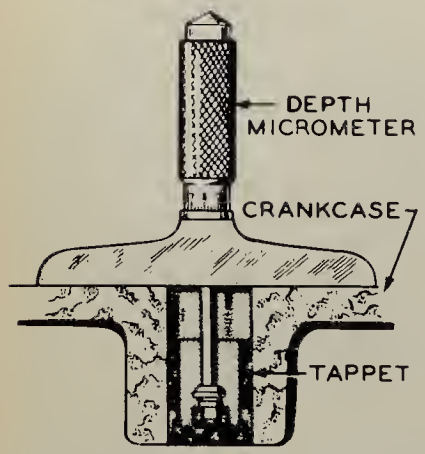


Fig. O205—To adjust injection pump timing on Model DJA, use depth micrometer to measure distance from pump tappet to mounting surface of crankcase as shown. Refer to text.

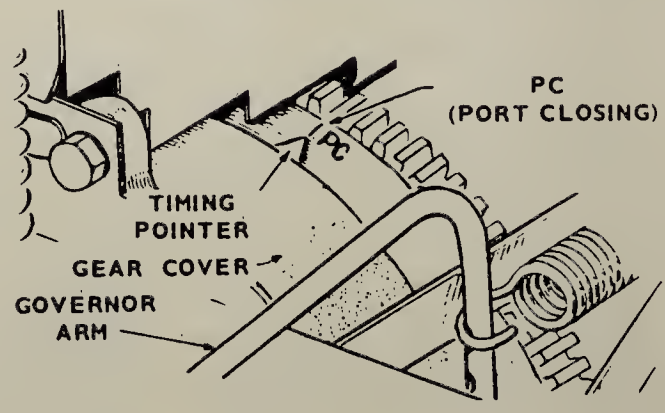


Fig. O206—Port closing injection timing mark is stamped on margin of diesel engine flywheels. Numerical value in degrees BTDC may be shown. Refer to text.

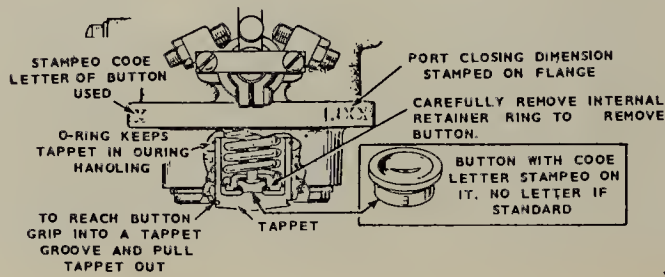

STAMPED CODE LETTER OF BUTTON USED
PORT CLOSING DIMENSION STAMPED ON FLANGE
CAREFULLY REMOVE INTERNAL RETAINER RING TO REMOVE BUTTON.
O-RING KEEPS TAPPET IN DURING HANDLING
BUTTON WITH CODE LETTER STAMPED ON IT. NO LETTER IF STANDARD
TO REACH BUTTON GRIP INTO A TAPPET GROOVE AND PULL TAPPET OUT
TAPPET

Fig. O207—Identification of timing button codes and port closing dimensions are stamped on mounting flange of PSU injection pumps. Note placement of timing button under tappet. Refer to text.

GROUP 1				GROUP 2				GROUP 3			
CODE	PART NO.	SIZE		CODE	PART NO.	SIZE		CODE	PART NO.	SIZE	
		Inch	mm			Inch	mm			Inch	mm
16 or S	147-0186	.134	3.404	1 or A	147-0147	.119	3.023	6 or F	147-0152	.101	2.565
15 or R	147-0187	.131	3.357	2 or B	147-0148	.116	2.946	7 or H	147-0153	.098	2.489
14 or P	147-0188	.128	3.251	3 or C	147-0149	.113	2.870	8 or I	147-0154	.095	2.413
13 or N	147-0189	.125	3.175	4 or D	147-0150	.110	2.794	9 or K	147-0155	.092	2.337
12 or M	147-0190	.122	3.099	5 or E	147-0151	.107	2.718	10 or L	147-0156	.089	2.261
				11 or STD	147-0161	.104	2.642				

Fig. O208—Table of timing button codes and thicknesses for setting injection timing on PSU pumps. Refer to text.

ing mark on flywheel is aligned with timing pointer as shown in Fig. O206. Remove timing hole screw from mounting flange of pump and insert a ⅛-inch (3mm) brass wire into timing hole as shown in Fig. O209. Rotate pump face gear until gear locks as wire engages timing recess. Reinstall pump onto crankcase using correct thickness of mounting shims as stamped on the crankcase. This shim pack controls mesh of pump drive and driven gears. Tighten pump mounting cap screws to a torque of 15-16 ft.-lbs. (20-22 N·m). Remove brass wire and reinstall timing hole plug. Reconnect fuel lines and throttle linkage. Bleed air from fuel system.

METHOD II. Use this procedure to time pump when dimensions from old pump are not available. Begin by installing pump which has been fitted with standard timing button (may be unmarked or marked number 11). Refer to Fig. O210 and remove cap nut from delivery valve and delivery valve holder, then lift out delivery valve spring. Reinstall holder and cap nut. Note that early models do not have a delivery valve holder.

Rotate flywheel until PC mark on flywheel is about 15° from timing pointer in compression stroke of number 1 cylinder. Place fuel control at full speed position. Disconnect high pressure line from number 1 injector. Operate transfer pump priming lever (fuel should flow from disconnected injector line) while slowly turning flywheel clockwise. When fuel flow from line stops, this is port closing point and beginning of injection. At this point, port closing (PC) mark on flywheel should be aligned with timing pointer if timing button is correct.

If timing pointer is ahead of port closing mark, timing is early and a thinner button is needed. If timing pointer is between PC and TDC marks, timing is late and a thicker button must be installed. To select correct button size, carefully measure space between PC mark and timing pointer. Each 0.100 inch (2.54 mm) on flywheel circumference is equivalent to 0.003 inch (0.076 mm) button thickness. Refer to table in Fig. O208.

EXAMPLE. Standard button installed in pump for test is 0.104 inch (2.642 mm) thick. Flow of fuel stops 0.2 inch (5.08 mm) after PC mark is passed indicating late timing. Referring to table in Fig. O208, it will be noted that button of Code 4 or D is 0.110 inch (2.794 mm) thick or 0.006 inch (0.152 mm) thicker than standard button. Installing this button in place of test button should time injection pump correctly.

After pump is correctly timed, reinstall delivery valve spring. Tighten delivery valve holder to a torque of 65-70 ft.-lbs.. (90-95 N·m) and cap nut to 55-60 ft.-lbs. (75-80 N·m). Complete installation of pump as previously outlined in this section.

BRYCE AND KIKI INJECTION PUMPS. Later Model DJE may be equipped with a Bryce or Kiki injection pump. Bryce and Kiki injection pumps are similar with no difference in servicing. Refer to Fig. O211 for view of pump. Injection pump timing should occur at 14-22° BTDC. Shims between the injection pump and adapter are used to adjust injection pump timing. If injection pump, adapter or gasket is new, follow procedure in Method I to time injection pump. If pump, adapter or gasket is not renewed or pump timing is to be checked, follow timing procedure in Method II.

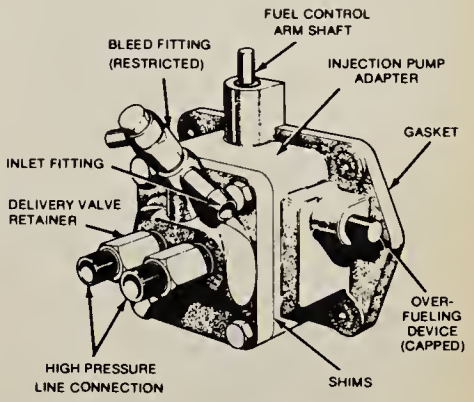


Fig. O211—View showing Bryce or Kiki fuel injection pump used on later Model DJE.

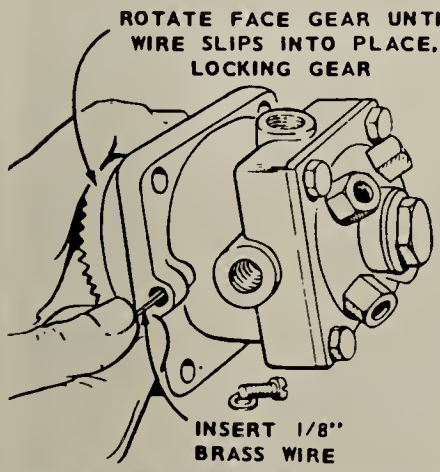
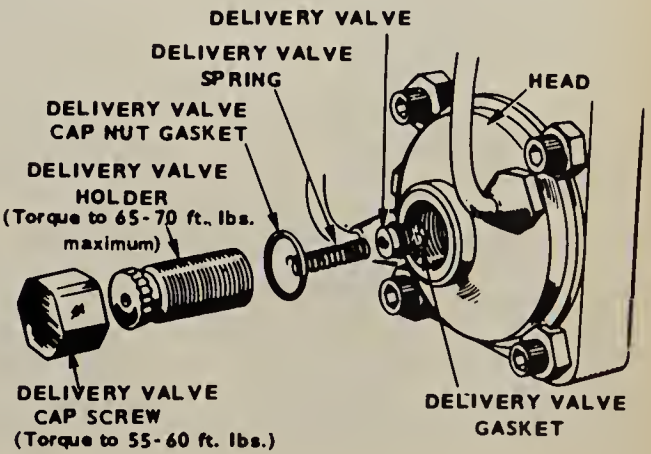


Fig. O209—Insert a brass wire into pump timing hole to lock PSU pump when timing and installing pump.

Fig. O210—Exploded view of delivery valve assembly of PSU injection pump. Note that only delivery valve spring is removed when using Method II to time two and four cylinder engines. Refer to text for procedure.


DELIVERY VALVE
DELIVERY VALVE SPRING
HEAD
DELIVERY VALVE CAP NUT GASKET
DELIVERY VALVE HOLDER (Torque to 65-70 ft. lbs. maximum)
DELIVERY VALVE CAP SCREW (Torque to 55-60 ft. lbs.)
DELIVERY VALVE GASKET

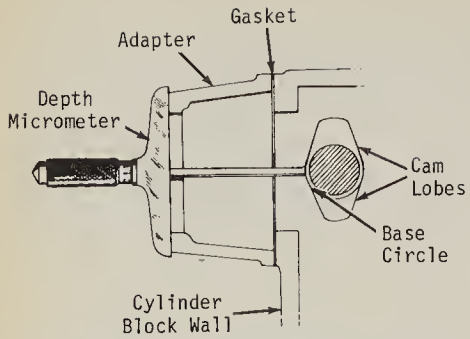


Fig. O212—Measure distance from adapter face to base circle of cam lobe to determine shim thickness for correct injection timing. Refer to text.

METHOD I. To determine thickness of shims for correct injection pump timing, install gasket and adapter then secure adapter with cap screws tightened to 20-24 ft.-lbs. (27-33 N·m). Using a depth mircrometer, measure distance from adapter face to base circle of either camshaft lobe as shown in Fig. O212. Subtract this reading from the standard dimension of 3.2598 inches (82.8 mm) and the result is the required shim thickness between pump and adapter. Note that on early DJE models the standard dimension is 3.2540 inches)82.652 mm) and "3.2540" is printed adjacent to pump on engine. Shims are available in thicknesses of 0.002, 0.003, 0.006, 0.010, 0.014 and 0.018 inch (0.051, 0.076, 0.152, 0.254, 0.356 and 0.457 mm). Tighten pump mounting screws to 20-24 ft.-lbs. (27-33 N·m).

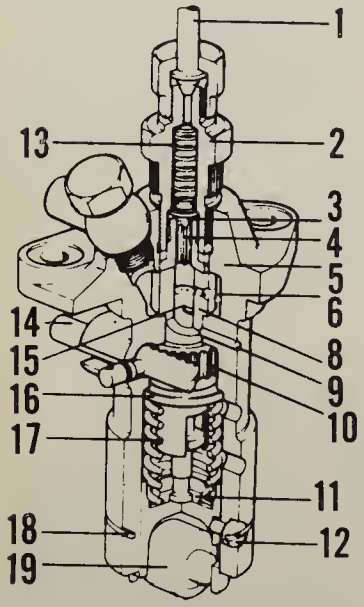


Fig. O213—Cross-sectional view of Bryce or Kiki injection pump.

1. Delivery tube
2. Delivery valve holder
3. Volume reducer
4. Delivery valve
5. Pump housing
6. Suction chamber
8. Plunger barrel
9. Pin
10. Control sleeve
11. Lower spring seat
12. Guide pin
13. Delivery valve spring
14. Control rack
15. Plunger
16. Upper spring seat
17. Plunger spring
18. Snap ring
19. Tappet

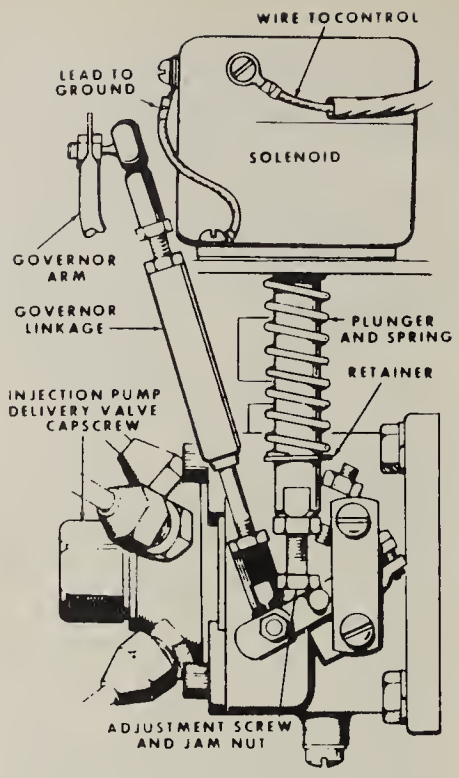


Fig. O214—Installed view of fuel solenoid. Refer to text.

METHOD II. If pump, adapter or gasket have not been renewed, the following spill timing procedure may be used to check injection pump timing.

Disconnect high pressure fuel line of cylinder being timed from injection pump. Unscrew delivery valve holder (2—Fig. O213) and remove valve spring (13), volume reducer (3) and delivery valve (4), then reinstall delivery valve holder (2). Attach a spill pipe made of old injector line with a gland nut to delivery valve holder and aim spill pipe at a receptacle to catch discharged fuel. Move fuel control arm toward front of engine to full fuel position while simultaneously holding plunger in on fuel shut-off solenoid. Operate fuel transfer pump while simultaneously rotating flywheel slowly clockwise until fuel just stops flowing from spill pipe. Injection pump port is now closed and PC mark on flywheel and timing pointer should be aligned as shown in Fig. O206. If PC mark is not present on flywheel, measure around flywheel rim from TC mark. A distance of 0.1 inch (2.54 mm) equals one degree of crankshaft rotation. Injection timing is adjusted using shims (Fig. O211) installed between pump and adapter. Shims are available in thicknesses of 0.002, 0.003, 0.006, 0.010, 0.014 and 0.018 inch (0.051, 0.076, 0.152, 0.254, 0.356 and 0.457 mm). Tighten pump retaining screws to 20-24 ft.-lbs. (27-33 N·m). Reinstall delivery valve (4—Fig. O213), volume reducer (3) and valve spring (13) after timing adjustment. Tighten delivery valve holder (2) to 29-33 ft.-lbs. (40-45 N·m) on Bryce pump or 44-47 ft.-lbs. (60-64 N·m) on Kiki pump.

Injection pump timing for remaining cylinder may be checked using above procedure. Timing differential between cylinders should be 2.5 degrees or less.

GOVERNOR (FUEL) SOLENOID. This special-purpose solenoid is an optional item usually associated with two-speed governors furnished on some engines. It is referred to as a governor solenoid because it overrides governor control of injection pump throttle lever.

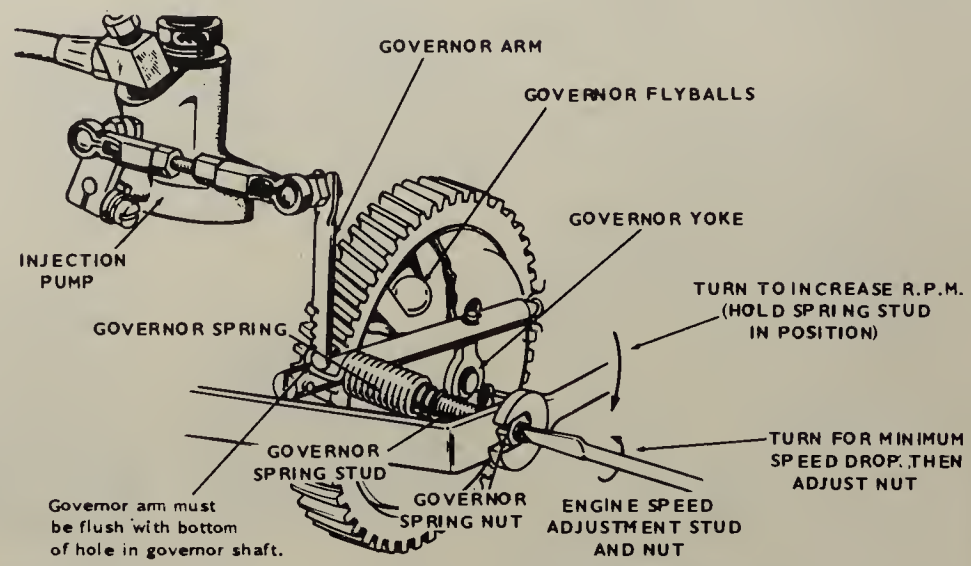

GOVERNOR ARM
GOVERNOR FLYBALLS
GOVERNOR YOKE
INJECTION PUMP
TURN TO INCREASE R.P.M. (HOLD SPRING STUD IN POSITION)
GOVERNOR SPRING
TURN FOR MINIMUM SPEED DROP, THEN ADJUST NUT
GOVERNOR SPRING STUD
GOVERNOR SPRING NUT
ENGINE SPEED ADJUSTMENT STUD AND NUT
Governor arm must be flush with bottom of hole in governor shaft.

Fig. O215—View of early governor mechanism to show points of adjustment. Governor shown is typical of constant speed type used on early air-cooled diesel models.

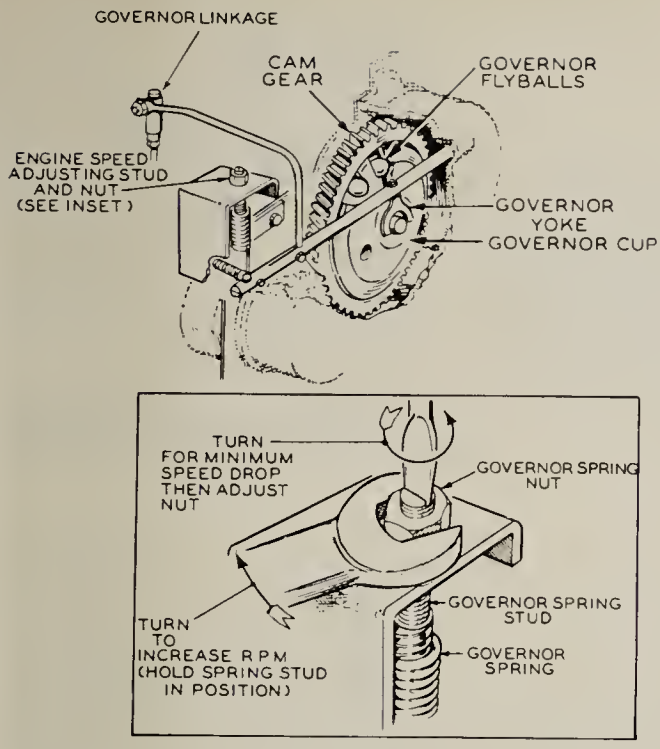


Fig. O216—View of governor linkage on early liquid-cooled models.

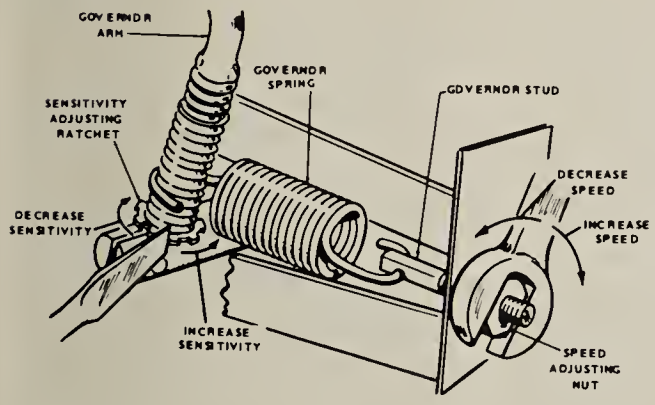


Fig. O217—Late governor mechanism showing adjustment on later air-cooled and liquid-cooled models. Refer to text.

Refer to Fig. O214 for typical mounting arrrangement.

When solenoid is energized by current flowing through its windings, plunger is retained within solenoid body and control of throttle is by governor action. When no current is flowing and solenoid de-energizes, plunger spring forces plunger outward against pump operating lever to hold lever in fuel shut-off position.

TESTING. Use a 12 volt input to check operation of solenoid plunger. Series-connected ammeter should indicate about 1 amp through holding coil when plunger is withdrawn into solenoid. If current exceeds 1 amp by a significant amount, then switch contacts for separate retractor winding did not open when plunger was drawn up. Resulting excess current will overheat solenoid. Check for plunger sticking in solenoid recess or for excessive tension on high speed governor spring. Plunger must fully retract to contact this switch, so a thorough check of possible causes of trouble is important. Renew solenoid assembly if defective.

ADJUSTMENT. With current "OFF", solenoid de-energized, loosen jam nut and turn adjustment screw (Fig. O214) as necessary to hold pump operating lever in fuel shut-off position. Tighten jam nut, then test for proper start-stop operation.

GOVERNOR

Flyball type mechanical governors are used on all engines. Governed speeds are 1800 rpm for 60 Cycle AC Generator, 1500 rpm for 50 Cycle AC Generator and 1750 rpm for DC Battery Charger. Recommended governed speed is stamped on generator nameplate. It should be possible to adjust governed speed to within 3 cycles (hertz) per second (90 engine rpm) and an adjustment of 2 cps (60 rpm) is usually attainable. For accurate speed adjustment, use of a reed type frequency meter on AC generator output is recommended by manufacturer over use of a mechanical tachometer.

To adjust governor linkage, proceed as follows: With engine not running, disconnect injection pump throttle link from governor arm and adjust the link, if necessary, until link can be reconnected with injection pump throttle arm in wide open position.

Two different types of governor linkage have been used. Refer to Fig. O215 for linkage on early air-cooled models or to Fig. O216 for early liquid-cooled models. Sensitivity is adjusted by turning adjustment stud in or out of governor spring. Engine speed is adjusted by turning governor spring nut while holding stud from turning. On late air-cooled and liquid-cooled models, governor spring nut controls engine speed while sensitivity is adjusted by turning the ratchet nut on governor arm as shown in Fig. O217.

Two- and four-cylinder engines (DJB, DJBA, DJC) may be furnished with a variable speed governor as shown in Fig. O218 instead of constant speed type. Variable speed is controlled by a ratchet locking throttle lever or by a solenoid control attached to auxiliary

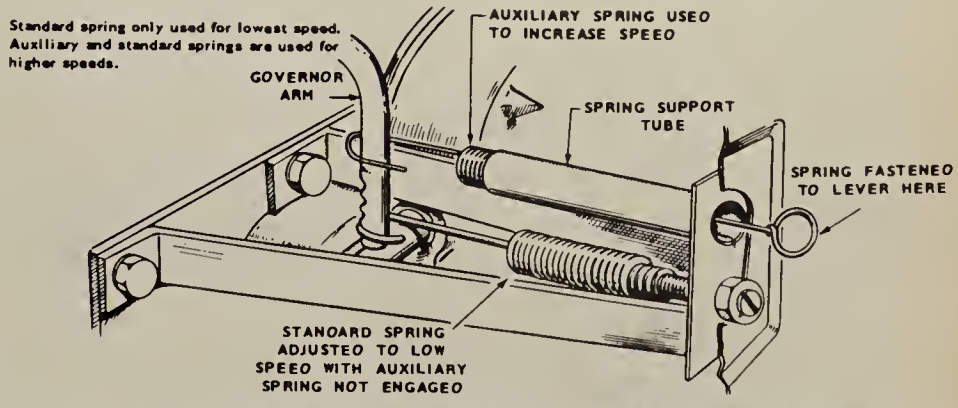

Standard spring only used for lowest speed. Auxiliary and standard springs are used for higher speeds.
AUXILIARY SPRING USED TO INCREASE SPEED
GOVERNOR ARM
SPRING SUPPORT TUBE
SPRING FASTENED TO LEVER HERE
STANDARD SPRING ADJUSTED TO LOW SPEED WITH AUXILIARY SPRING NOT ENGAGED

Fig. O218—View of variable speed governor auxiliary spring in relation to constant speed governor spring shown in preceding figures. Refer to text.

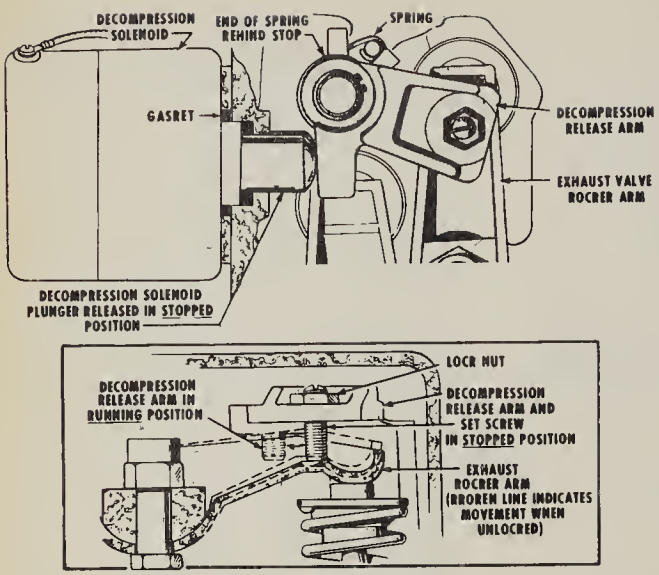

DECOMPRESSION SOLENOID
END OF SPRING BEHIND STOP
SPRING
GASKET
DECOMPRESSION RELEASE ARM
EXHAUST VALVE ROCKER ARM
DECOMPRESSION SOLENOID PLUNGER RELEASED IN STOPPED POSITION
LOCK NUT
DECOMPRESSION RELEASE ARM IN RUNNING POSITION
DECOMPRESSION RELEASE ARM AND SET SCREW IN STOPPED POSITION
EXHAUST ROCKER ARM (BROKEN LINE INDICATES MOVEMENT WHEN UNLOCKED)

Fig. O219—Two-position view of compression release mechanism used on Model DJA engine. Upper view is downward, in line with cylinder bore. Lower view shows cross section with decompression release holding rocker arm down and exhaust valve open as discussed in text.

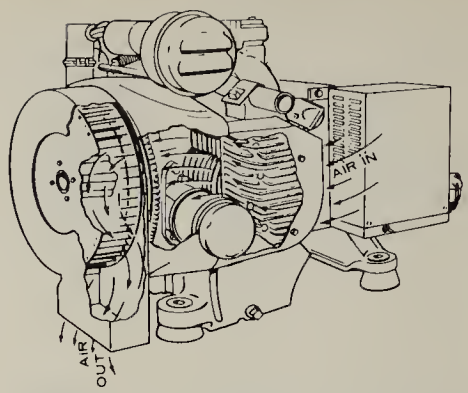


Fig. O221—Typical cooling air flows in Vacu-Flo system used for closed compartment installation.

governor spring (Fig. O218) to override standard constant speed spring. Basic speed and sensitivity adjustments remain the same with variable higher speeds set at desired levels by throttle control or solenoid position.

COMPRESSION RELEASE MECHANISM

Refer to Fig. O219 for top and cross section view of compression release mechanisim used on Model DJA (one cylinder) engine. Decompression is obtained by the release arm adjusting screw riding up the ramp of exhaust valve rocker arm, holding exhaust valve slightly open when release mechanism is effective. The compression release arm pivots on its axle pin and is spring actuated to both the RELEASE and RUNNING positions. The coil spring on release arm hub is tensioned to move arm into RUNNING position. A stronger spring located on solenoid plunger moves the arm to RELEASE position when solenoid is NOT energized. When current is routed to solenoid, the plunger is drawn away from release arm and arm is allowed to move to RUNNING position.

ADJUSTMENT. To adjust the compression release mechanism, first remove decompression solenoid and rocker arm cover. Turn crankshaft until exhaust valve is closed and push rod is loose. Loosen locknut and back out adjusting screw on compression release arm about two turns; then, check to be sure release arm pivots back and forth easily without binding. Arm should move counterclockwise against spring pressure and should snap back easily to RUNNING position when released. Pivot arm fully counterclockwise against its stop and turn adjusting screw until it just touches rocker arm (rocker arm must be in contact with valve stem). Turn screw ONE additional turn to open valve the specified amount and secure by tightening locknut.

CAUTION: If screw is tightened by more than one turn, valve head might strike piston. Manually move release arm to RUNNING position (clockwise) and check to be sure that some clearance exists between valve rocker arm and set screw.

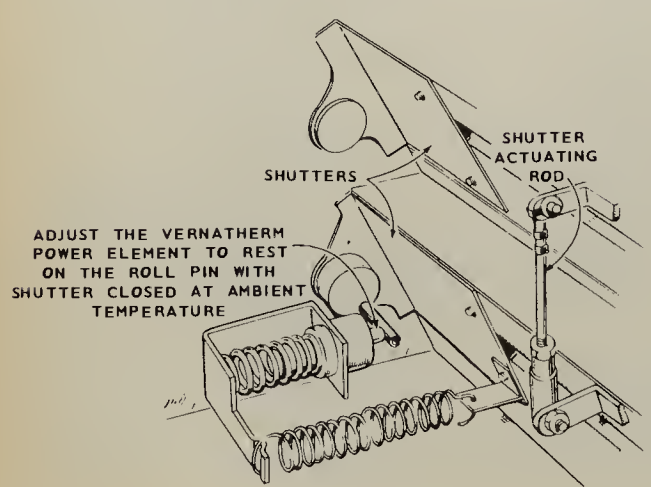

SHUTTER ACTUATING ROD
SHUTTERS
ADJUST THE VERNATHERM POWER ELEMENT TO REST ON THE ROLL PIN WITH SHUTTER CLOSED AT AMBIENT TEMPERATURE

Fig. O220—View of thermostat controlled power shutter for pressure-cooled engines. Note adjustment. Refer to text for details.

On models with centrifugal switch, breaker point gap should be adjusted to 0.040 inch (1.0 mm).

AIR COOLING SYSTEM

Air cooling systems are used on Models DJA, DJB, DJBA, DJC and DJE to cool engine. Pressure cooling or Vacu-Flo cooling systems are used as outlined in the following sections.

PRESSURE COOLING. On models equipped with pressure cooling, free air is drawn by flywheel rotation into engine sheet metal housing through flywheel grille opening and is forced through cylinder cooling fins and out through a rear or side aperature.

Some engines may be equipped with a thermostat controlled shutter (Vernatherm) which allows engine compartment air to reach 120°F (50°C) before opening and becomes wide open at 140°F (60°C) for full ventilation of enclosure. Opening temperature of sensing element is not adjustable. To determine if this operating element is in working order, remove two screws which retain it to mounting bracket (note slotted holds for adjusting position) and test it by application of heat. Opening should begin at 120°F (50°C) and plunger should be fully extended at 140°F (60°C). Total movement should be at least 13/64 inch (5 mm). Reinstall so that plunger when fully withdrawn into element body just touches roll pin as in Fig. O220 with shutter completely closed at ambient (free air) temperature.

If shutter operation is unsatisfactory, check for a weak shutter return (closing) spring and examine nylon shutter bearings for dirt or damage. Clean and renew as necessary.

VACU-FLO COOLING. This system is designed for cooling industrial power plants which are installed in a closed compartment. Note in Fig. O221 that

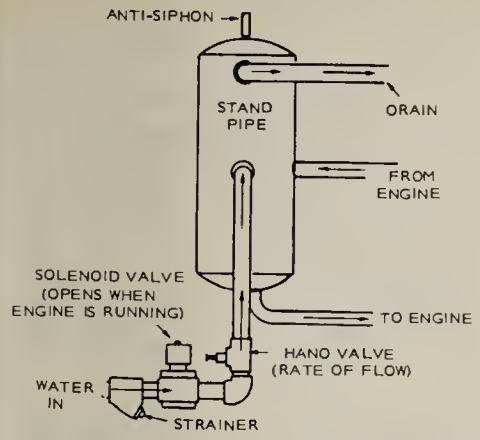


Fig. 0223—Drawing showing coolant flow to and from standpipe.

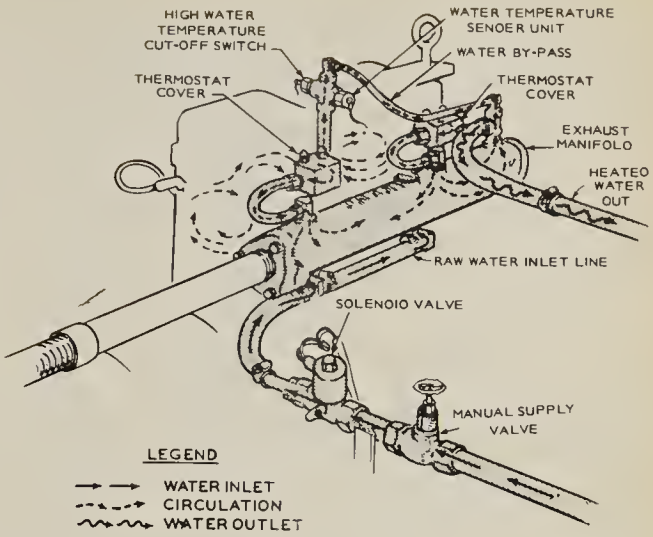


Fig. 0223—Drawing showing coolant flow on models using external water source routed through the manifold.

flow of coolant air is drawn through engine shroud and cooling fins and forced out by flywheel blower through a vent or outside duct. Flow is in reverse direction from that of pressure-cooled engines.

IMPORTANT. If flywheel or flywheel blower is renewed, be sure that new part is correct for engine cooling system, whether pressure or Vacu-Flo.

Air volume requirement for proper cooling of these engines, expressed in cubic feet per minute is specified for each engine in factory-furnished operator's manual. Dependent upon engine size, this may range from 300 to 1600 cfm (8.5-45.3 m^3). Duct and vent sizes are detailed for each model and type of cooling system.

HIGH TEMPERATURE CUT-OFF. Some larger engine models are equipped with a high temperature safety switch for protection from overheating. Switch is normally closed, but opens to stop engine if compartment air temperature rises to 240°F (115°C) due to problem in cooling system caused by blockage or shutter failure to open. When engine compartment temperature drops to about 190°F (90°C), switch will automatically close and engine can be restarted.

LIQUID-COOLED SYSTEM

Liquid-cooled engines RDJC, RDJE, RDJEA and RDJF use either a radiator or external water source to cool engine. Refer to following sections for servicing.

RADIATOR SYSTEM. An automotive type radiator cooling system is used on some models. Note that cooling fan forces air through radiator and a belt driven water pump is mounted on front of engine. A bypass line is connected from the water pump to the water outlet on the cylinder head so water is circulated when the thermostat is contained inside the cylinder head water outlet.

Radiator capacity for all models is three gallons (11.3 liters). Do not use antileak type antifreeze on models equipped with coolant filters. Be sure adequate air circulation is possible around radiator, ducts and vents. Heated air should not be allowed to reenter cooling air stream.

EXTERNAL WATER SYSTEM. Some models may be equipped with a cooling system which routes water supplied from an external source through cooling passages in the engine block. No water pump is used as pressure is supplied at the water source. A solenoid valve shuts off water when the engine is not running while a supply valve controls rate of water flow. Three types of external water systems are used. In the direct flow system, water is routed directly to the engine block then discharged. In the standpipe system shown in Fig. 0222, water circulates through the engine then returns to a standpipe to be mixed with fresh, cool water. The hottest water rises in the standpipe and is drained off. In the wet manifold system shown in Fig. 0223, water is circulated around the exhaust manifold after passing through the engine block. Two 160°F (70°C) thermostats contained in housings attached to the cylinder heads must open before water enters the water jacket surrounding the exhaust manifold. A bypass line circulates water prior to thermostat opening. On all systems, the water discharge line must be sufficiently large so water flow is not impeded.

CRANKCASE BREATHER

The crankcase breather is located inside the rocker cover as shown in Fig. 0224. Crankcase breather (41) vents crankcase fumes into the intake port. Inspect breather after every 200 hours of operation.

REPAIRS

TIGHTENING TORQUES

Recommended tightening torques for all models are as follows:

Connecting rod	27-29 ft.-lbs. (37-39 N·m)
Cylinder head	44-46 ft.-lbs. (60-62 N·m)
Exhaust manifold	13-15 ft.-lbs. (18-20 N·m)
Flywheel	65-70 ft.-lbs. (88-95 N·m)
Fuel pump	15-20 ft.-lbs. (20-27 N·m)
Gearcase cover	15-20 ft.-lbs. (20-27 N·m)
Glow plug	10-15 ft.-lbs. (18-20 N·m)
Injection nozzle	20-21 ft.-lbs. (27-28 N·m)
Injection pump	15-16 ft.-lbs. (20-22 N·m)
Intake manifold	13-15 ft.-lbs. (18-20 N·m)
Rear bearing plate	40-45 ft.-lbs. (54-61 N·m)

CYLINDER HEAD

To remove the cylinder head, it is first necessary on liquid-cooled models to drain coolant and disconnect interfering hoses. Remove the decompression

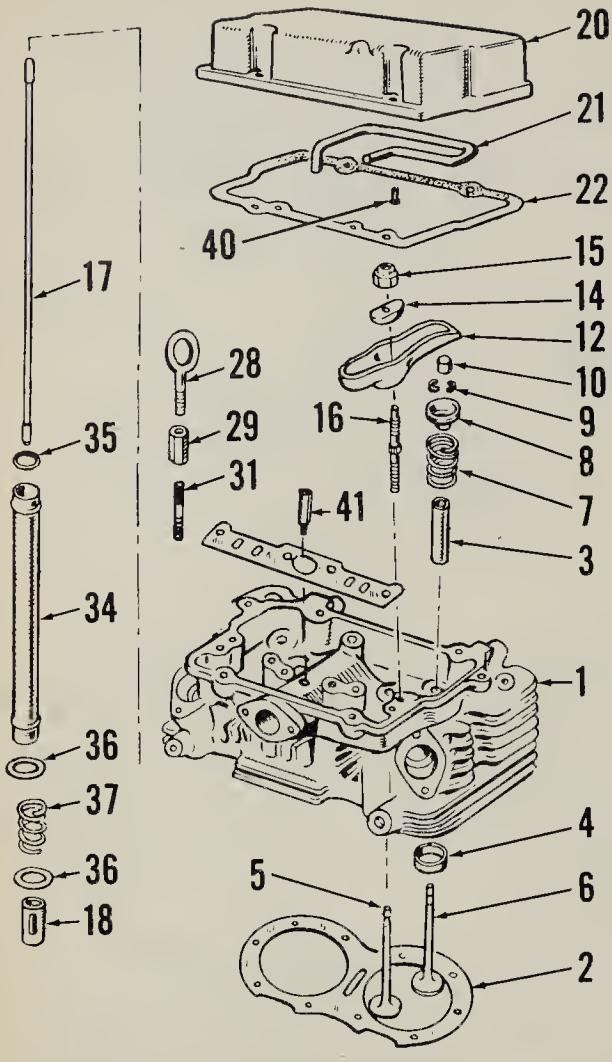


Fig. O224—Exploded view of typical cylinder head assembly. Model DJB is shown.

1. Cylinder head
2. Head gasket
3. Valve guide
4. Valve seat insert
5. Intake valve
6. Exhaust vlave
7. Valve spring
8. Spring retainer
9. Retainer locks
10. Valve stem cap
12. Rocker arm
14. Rocker ball pivot
15. Rocker locknut
16. Rocker arm stud
17. Tappet push rod
18. Tappet
21. Rocker oil line
22. Cover gasket
28. Lifting eyebolt
29. Extension nut
31. Cylinder stud
34. Push rod shield
35. "O" ring
36. Washer
37. Shield spring
40. Oil line screw
41. Crankcase breather

solenoid (DJA only), rocker box cover, fuel injector and manifolds. Push rods and push rod tube shields will be loose when head is removed. Refer to Fig. O224. Both intake and exhaust valve are equipped with release type valve rotator caps. Lift off and identify the caps as head is removed, so they can be reinstalled on the same valves when unit is reassembled.

To reinstall cylinder head, proceed as follows: Assemble cylinder head with new gasket onto cylinder block. Before tightening cylinder head cap screws on four-cylinder models, install exhaust manifold and tighten manifold nuts evenly to a torque of 13-15 ft.-lbs. (18-20 N·m). This will align exhaust ports with manifold. On all models, tighten cylinder head bolts in appropriate sequence shown in Fig. O225 to first step torque of 25-30 ft.-lbs. (34-41 N·m). Then tighten cap screws in same sequence to final torque of 44-46 ft.-lbs. (60-62 N·m). Wait a few minutes to allow gasket to compress, then retorque to 44-46 ft.-lbs. (60-62 N·m) following same tightening sequence.

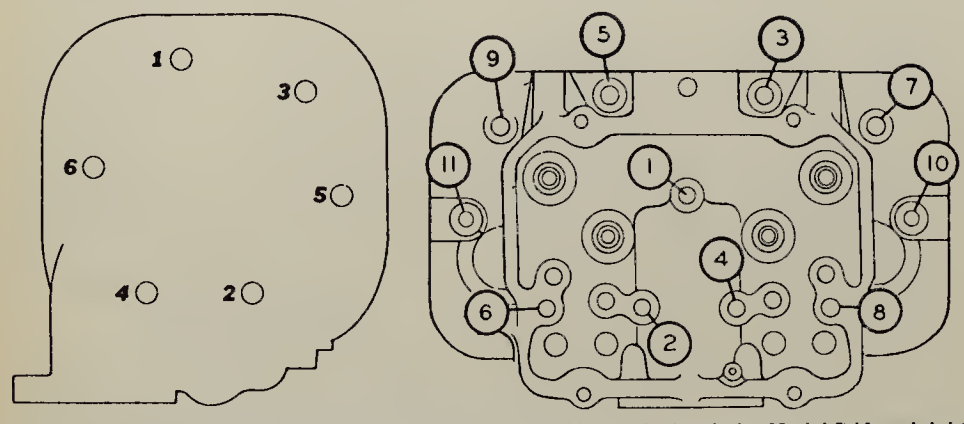


Fig. O225—Tightening sequence for cylinder head cap screws. Left view is for Model DJA and right view is for all other models. Refer to text.

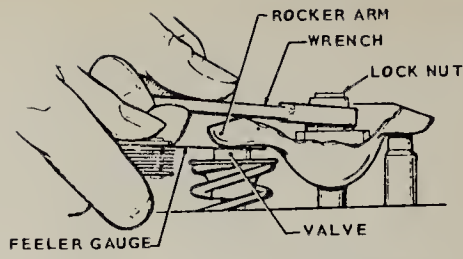


Fig. O226—Valve clearance is adjusted by turning rocker arm locknut while inserting proper size feeler gage between rocker arm and valve stem end. Refer to text.

Adjust valve clearance and compression release linkage (Model DJA) as outlined in appropriate paragraphs. Complete installation by reversing removal procedure. Cylinder head should be retorqued and valves readjusted after the first 50 hours of engine operation.

VALVE CLEARANCE ADJUSTMENT

Valve clearance should be set with engine cold and piston 10°-45° past TDC on power stroke. Valve clearance is adjusted by turning rocker arm stud locknut (Fig. O226) while inserting a feeler gage of proper thickness between rocker arm and valve stem.

NOTE: A torque of 4-10 ft.-lbs. (5-13 N·m) should be required to turn self-locking rocker arm nut. If turning torque is not within this range, threads are damaged and nut and/or rocker arm stud should be renewed.

On two-cylinder engines, be sure to move each piston past TDC on its power stroke before adjusting valves for each cylinder. On four-cylinder models, adjust valves in regular engine firing order (1-2-4-3). Begin with number 1 cylinder with piston 10°-45° past TDC on power stroke. Rotate crankshaft 180° (½ turn) for each successive cylinder in firing order.

Valve clearance should be 0.011 inch (0.28 mm) for intake and 0.008 inch (0.20 mm) for exhaust on Model DJA. Model DJB, prior to Specification D, calls for both intake and exhaust to be 0.004 inch (0.10 mm). Beginning with Specification D, intake should be 0.009 inch (0.23 mm) and exhaust 0.007 inch (0.18 mm). Models DJBA and DJC should also be set at 0.009 inch (0.23 mm) intake and 0.007 inch (0.18 mm) for exhaust. Model RDJC valve clearance is 0.011 inch (0.28 mm) for intake and 0.016 inch (0.40 mm) for exhaust. On Models RDJE, RDJEA and RDJF, clearance for both intake and exhaust is 0.017 inch (0.43 mm).

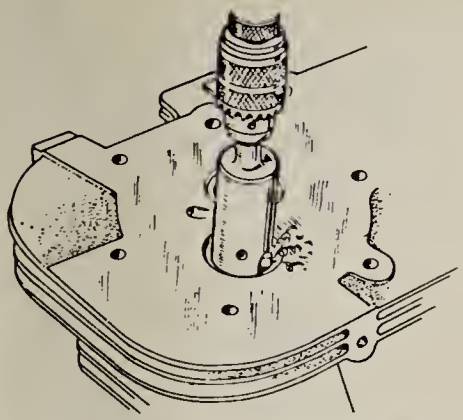


Fig. O227—Tool setup for removal of valve seat inserts. Adjust to cut 0.015 inch (0.4 mm) from edge of seat and take care not to bottom tool in counterbore.

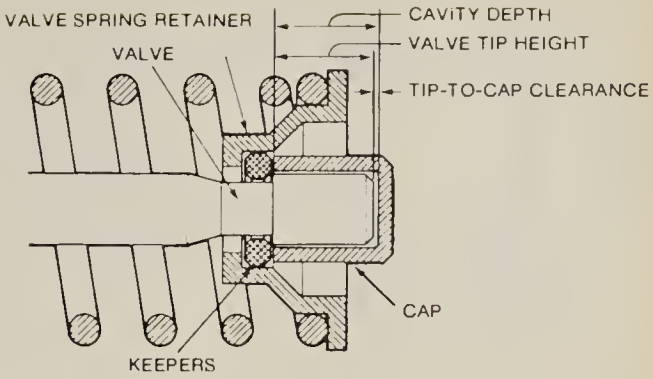


Fig. O229—Release-type valve rotators are used on all models. Clearance between valve stem end and cap should be checked whenever valves are serviced. Refer to text.

Manufacturer recommends readjusting valve clearance after every 500 hours of operation.

VALVE SYSTEM

All engines are equipped with renewable, insert type valve seats. Valve seat angle for intake and exhaust should be 45°. Intake valve face angle should be ground to 42° on all models and exhaust valve face angle should be 45°. Valve seat width should be 3/64 to 1/16 inch (1.2-1.6 mm). Manufacturer does not recommend handlapping valves to seats as sharp contact at seating surface could be destroyed. Apply Prussian Blue to valve face and rotate against seat to check seating surface.

Hardened valve seats are renewable. To remove old seat, use ONAN tool 420-0272 mounted in a drill press as shown in Fig. O227. Set tool to cut 0.015 inch (0.04 mm) from outer edge of seat. Seat material which remains may be easily peeled from counterbore. Use care not to damage counterbore.

Valve seat inserts are available in 0.002, 0.005, 0.010 and 0.025 inch (0.051, 0.127, 0.254 and 0.635 mm) oversizes as well as standard. Seat insert should have a 0.002-0.004 inch (0.05-0.10 mm) interference fit in its counterbore. Be sure counterbore is clean and free of burrs before installing insert. To make installation easier, heat cylinder head to 325°F (165°C) in an oven and chill valve seats with dry ice. Install immediately making certain insert is bottomed in counterbore.

After new seat has been installed and ground, temporarily install valve and check clearance between valve head and gasket surface of cylinder head. If clearance is less than 0.030 inch (0.76 mm), valve seat must be reground until recommended clearance is obtained.

Exhaust valve stem diameter for all models is 0.3405-0.3415 inch (8.649-8.674 mm). Intake valve stem diameter is as follows: Early Model DJA is 0.3405-0.3410 inch (8.649-8.661 mm) and late Model DJA is 0.3381-0.3420 inch (8.588-8.687 mm). Early Model DJB is 0.3405-0.3410 (8.649-8.661 mm) and late Model DJB has a tapered stem (Fig. 0228) which is 0.3385-0.3397 inch (0.860-0.863 mm) measured 2.96 inches (75.2 mm) from end and 0.3401-0.3411 inch (8.639-8.664 mm) at 1.18 inches (30.0 mm) from end. All DJBA models are 0.3405-0.3410 inch (8.649-8.661 mm) and all DJE, RDJC, RDJE and RDJEA models are 0.3405-0.3415 inch (8.649-8.674 mm). Early RDJE models are 0.3405-0.3415 inch (8.649-8.674 mm) while late models use a tapered stem intake valve (Fig. O228) which measures 0.3385-0.3397 inch (8.597-8.628 mm) at 2.96 inches (75.2 mm) from retainer end and 0.3405-0.3410 inch (8.649-8.661 mm) at 1.18 inches (30.0 mm) from end. Recommended stem to guide clearance is 0.0015-0.003 inch (0.038-0.076 mm) for intake and 0.003-0.005 inch (0.076-0.127 mm) for exhaust on all models.

Valve guides are interchangeable for intake and exhaust valves. After installation, both guides must be reamed to provide recommended valve stem operating clearance. When properly installed, guides should extend 11/32 inch (8.7 mm) above machined spring seat of head.

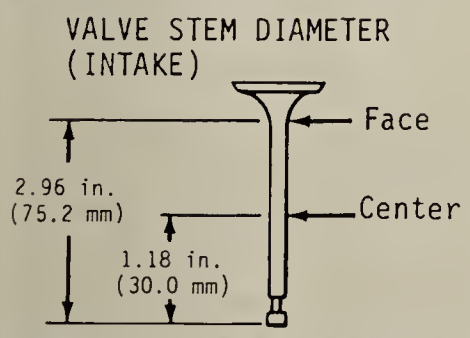


Fig. O228—Intake valve stem is tapered on late Models DJB, DJC and RDJF. Measure stem diameter at points indicated when checking condition of valve. Refer to text.

Valve springs are identical for intake and exhaust valves. Springs should have a free length of 1⅞ inches and should test 45-49 pounds (200-218 N) when compressed to a length of 1.528 inches (38.81 mm).

All engines are equipped with release-type valve rotators on both intake and exhaust valves. The rotator cap (Fig. O229) releases keeper tension as the valve is pushed off its seat. This allows the valve to float and rotate during operation. For proper operation, clearance between end of valve and cap should be between 0.001-0.005 inch (0.025-0.127 mm). Too little clearance will prevent valve rotation and too much clearance may cause valve breakage. To check clearance, remove cap and measure depth of cavity in cap. Measure valve tip height from keeper and subtract this dimension from cap depth to determine clearance. If clearance is not within specifications, renew parts as necessary. When reassembling, place a drop of oil on end of valve stem before installing cap.

INJECTOR

WARNING: Fuel emerges from injector with sufficient force to penetrate the skin. When testing, keep your person clear of the nozzle spray.

All engines except later DJE models are equipped with American Bosch pintle type injector nozzles. Opening pressure is factory adjusted to 1900-1950 psi (13100-13450 kPa). However, pressure may decrease to approximately 1750 psi (12065 kPa) as nozzle spring takes a set. Later Model DJE is equipped with Diesel Kiki injection nozzles. Opening pressure is factory adjusted to an initial setting of 2130-2200 psi (14685-15170 kPa). Pressure may decrease to approximately 1950 psi (13445 kPa) as nozzle spring takes a set.

If engine does not start or does not run properly and the injector is suspected of being at fault, remove and reposition the unit where spray pattern can be observed or attach unit to a nozzle tester. Turn engine over with starter or actuate

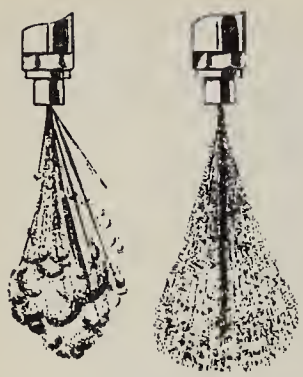


Fig. O230—Comparison view of poor (left) and good (right) injector spray patterns. Refer to details.

tester handle. Spray pattern should be conical in shape with a solid core as shown in right-hand view, Fig. O230. If spray pattern is ragged or not symmetrical or if nozzle drips, install a new or rebuilt unit or disassemble, clean and adjust the injector unit. If spray pattern is satisfactory and tester unit is available, adjust opening pressure to pressure specified in preceding paragraph. Pressure is adjusted by turning pressure adjusting screw shown in Fig. O231. Screw may be turned after unscrewing plug and loosening cover. Tighten cover to 45-50 ft.-lbs. (61-68 N·m) after final screw adjustment and reinstall plug. Unscrew cover (C) and loosen locknut (L) on Kiki and early Bosch injectors to turn adjusting screw. After final screw adjustment, tighten locknut (L) and cover (C) to 45-50 ft.-lbs. (61-68 N·m). Do not disassemble a unit which can be returned to service without disassembly.

NOTE: Do not attempt to disassemble, clean or overhaul an injector unit unless the proper tools are available.

Fig. O231 shows a cross-sectional view of nozzle holder and nozzle valve. Be extremely careful when nozzle unit is handled not to strike or damage the protruding nozzle valve pintle. Any damage will deform the spray pattern and make the unit unfit for further use. A diesel nozzle tool set, ONAN part number 420-0208, is available for servicing nozzles. When nozzle is disassembled, be sure to keep all parts for each nozzle separated as parts must not be interchanged. Clean dirt and carbon from nozzle components using solvent and tools from cleaning kit.

Nozzle valve needle must slide freely in valve body. To check, first thoroughly rinse needle and seat in clean diesel fuel. With parts wet with diesel fuel, withdraw needle about one-third of the way out of the valve body. With valve held at 45° angle, needle should slide back to its seat by its own weight. If it does not, reclean or renew nozzle valve assembly.

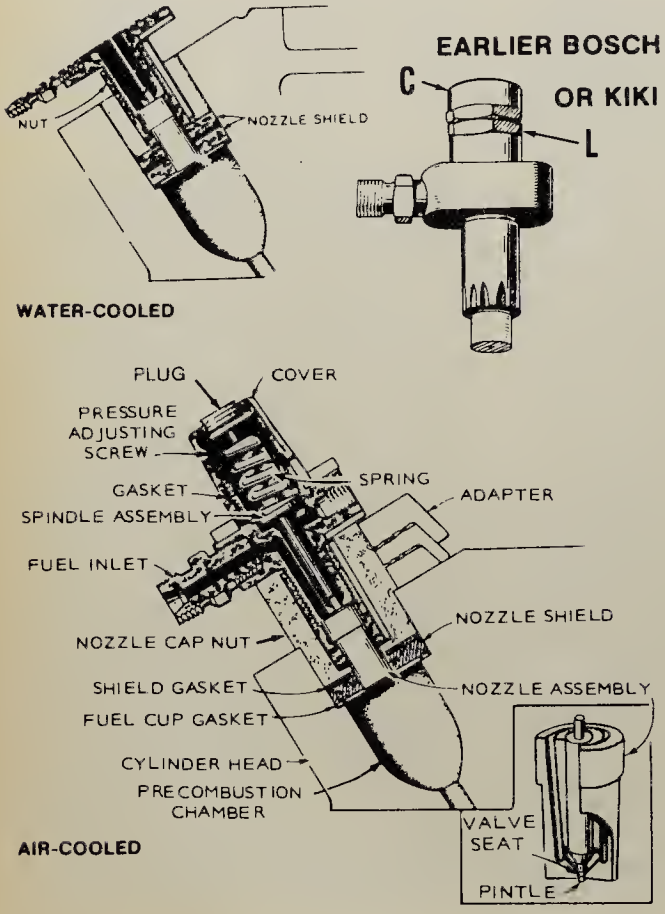


Fig. O231—View of injector assemblies. On late Bosch injector, a plug is unscrewed for access to pressure adjusting screw. On Kiki and early Bosch injectors, cover (C) must be removed for access to pressure adjusting screw.

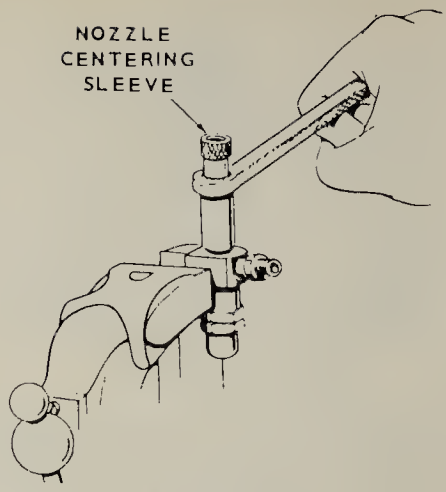


Fig. O232—Centering sleeve, part of ONAN tool set number 420-0208, is used to center nozzle body in cap nut when reassembling nozzle.

When reassembling injector, nozzle body must be perfectly centered in cap nut. A centering sleeve (Fig. O232), part of tool kit 420-0208, is used to center nozzle body and initially tighten cap nut. Then, remove centering sleeve and tighten cap nut to a torque of 50-55 ft.-lbs. (70-75 N·m).

When reinstalling injector, be sure to renew nozzle heat shield and gasket assembly in cylinder head injector bore. Tighten injector retaining cap screws to a torque of 20-21 ft.-lbs. (27-28 N·m).

INJECTION PUMP

Model DJA is equipped with an American Bosch Model PLB injection pump, later Model DJE is equipped with either a Bryce of Kiki injection pump while all other models are equipped with an American Bosch PSU injection pump.

Unless the shop is equipped with the necessary calibration stand and overhaul data, disassembly of pump should not be attempted.

When injection pump is removed, time and bleed the unit during reinstallation, and adjust governor linkage, as outlined in previous MAINTENANCE para-

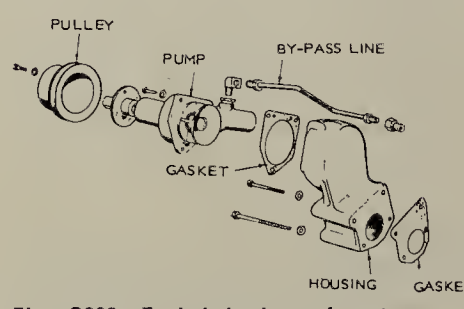


Fig. O233—Exploded view of water pump assembly.

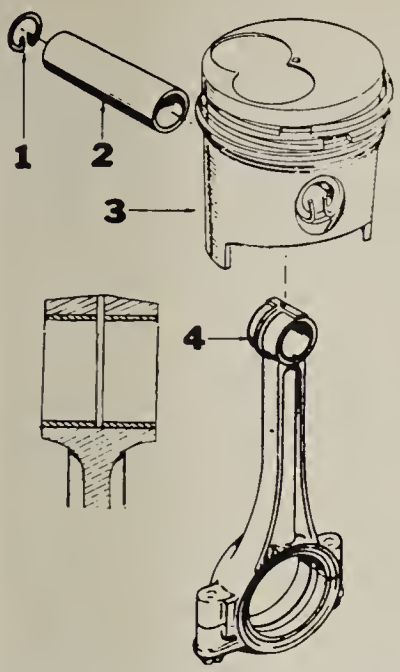


Fig. O234—Exploded view of piston and connecting rod assembly. Two bushings are used in upper end of rod to provide an oil groove at center of rod bore.

1. Retaining ring
2. Piston pin
3. Piston
4. Connecting rod

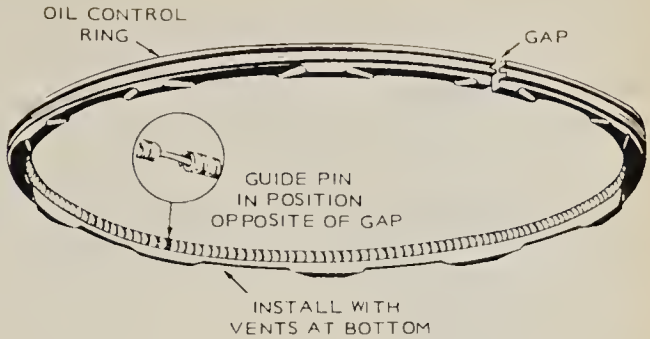
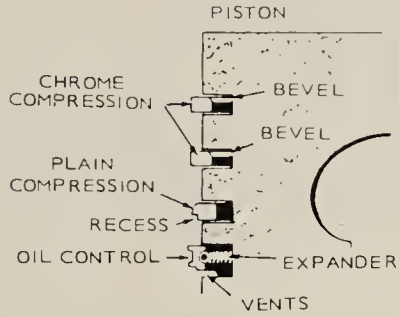


Fig. O235—Cross section of piston rings and piston showing ring arrangement. Ring end gaps should be staggered equally around piston but should not be in line with piston pin bore.



graphs. Tighten injection pump mounting screws alternately and evenly to a torque of 18-21 ft.-lbs. (24-28 N·m) on Model DJA and 15-16 ft.-lbs. (20-22 N·m) on all other models when unit is reinstalled.

WATER PUMP

Models RDJC, RDJE, RDJEA and RDJF equipped with a radiator cooling system use a water pump to circulate coolant. Refer to Fig. O233 for an exploded view of water pump assembly. Pump bearings are permanently sealed and packed with a lubricant. Bearings and impeller seal are renewable.

Manufacturer recommends using a mixture of ethylene glycol antifreeze and water as a coolant in both summer and winter. The antifreeze contains rust and corrosion inhibitors that protect the cooling system. Coolant should be changed every year.

CONNECTING ROD

Connecting rod and piston unit can be removed from above after removing cylinder head and engine oil base. Be sure to remove ring ridge from top of cylinder bore before attempting to remove piston. The forged connecting rod contains renewable, precision bearing inserts in large end. Bearings are available in undersizes of 0.010, 0.020 and 0.030 inch (0.254, 0.508 and 0.762 mm) as well as standard.

Standard crankpin diameter for all models is 2.0597-2.0605 inches (52.316-52.337 mm) with recommended diametral clearance of 0.001-0.0033 inch (0.025-0.084 mm).

Two bushings are used in piston pin end of rod. Bushings should be pressed in from each side of bore until flush with outer surfaces of rod. This will leave an oil groove space of approximately 1/16 inch (1.6 mm) in center of rod bore. Drill a 3/16 inch (5 mm) oil hole through bushings at top of rod before reaming bushings. Final sizing of bushing calls for a diametral clearance of 0.0002-0.0007 inch (0.005-0.018 mm). Standard diameter of piston pin is 0.9899-0.9901 inch (25.143-25.148 mm) with 0.002 inch (0.05 mm) oversize pin available.

When installing assembled piston and connecting rod, notch or "FRONT" mark on piston should face front of engine and witness marks on connecting rod and cap must be aligned. On engines after Specification P, valve relief cut-outs on head of piston should face in same direction as stamped reference numbers on connecting rod or raised witness marks of no number is imprinted on rod. Install piston and rod unit with reference numbers and valve relief cut-outs facing camshaft side of engine. On all models, tighten connecting rod cap screws to a torque of 27-29 ft.-lbs. (37-39 N·m).

PISTON, PIN, RINGS AND CYLINDER

Piston is equipped with three compression rings and one expander type oil control ring. Compression rings are marked "TOP" or otherwise identified for correct installation. Oil control ring should be installed with vents toward bottom of piston. Refer to Fig. O235. Rings should be postitioned with end gaps staggered equally around piston. Guide pin in expander should be opposite (180°) from end gap of oil control ring. No gap should be in line with piston pin bore.

Piston ring end gap should be measured with ring positioned squarely in cylinder bore. Recommended end gap for all rings is 0.010-0.020 inch (0.25-0.50 mm). Piston ring groove wear can be checked by installing a new ring in piston groove and measuring ring side clearance in groove. Recommended clearance is 0.003-0.005 inch (0.08-0.13 mm). Piston should be renewed if clearance exceeds 0.006 inch (0.15 mm).

Standard cylinder bore diameter is 3.4995-3.5005 inches (88.887-88.913 mm) for Models DJE, RDJE, RDJEA and RDJF. Standard cylinder bore diameter for all other models is 3.2495-3.2505 inches (82.537-82.563 mm). Some engines are factory equipped with 0.005 inch (0.13 mm) oversize piston and rings. These engines are identified by an "E" following the serial number. Pistons and rings are available in oversizes of 0.005, 0.010, 0.020, 0.030 and 0.040 inch (0.127, 0.254, 0.0508, 0.762 and 1.016 mm) as well as standard size. Recommended piston skirt clearance in cylinder is 0.0055-0.0075 inch (0.140-0.191 mm) when measured 90° from piston pin.

Piston pin should be a thumb push fit into piston at room temperature. If pin is excessively loose, renew pin and/or

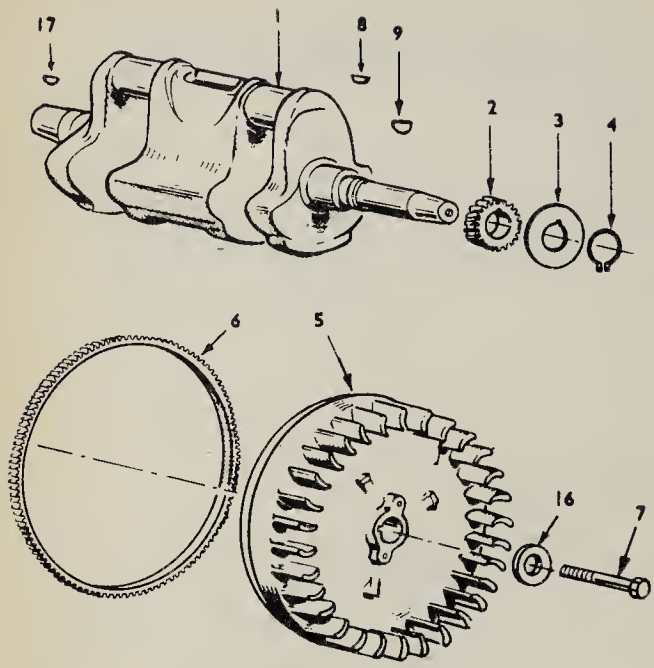


Fig. O236—Exploded view of crankshaft and flywheel typical of "J" series. Model DJB shown.

1. Crankshaft
2. Timing gear
3. Retainer washer
4. Lock ring
5. Flywheel
6. Ring gear
7. Flywheel cap screw
8. Timing gear key
9. Flywheel key
16. Flywheel wasber
17. Drive gear key

piston. A 0.002 inch (0.05 mm) oversize piston pin is available. For easier pin installation, piston may be heated in hot water or an oven prior to assembly.

CRANKSHAFT AND BEARINGS

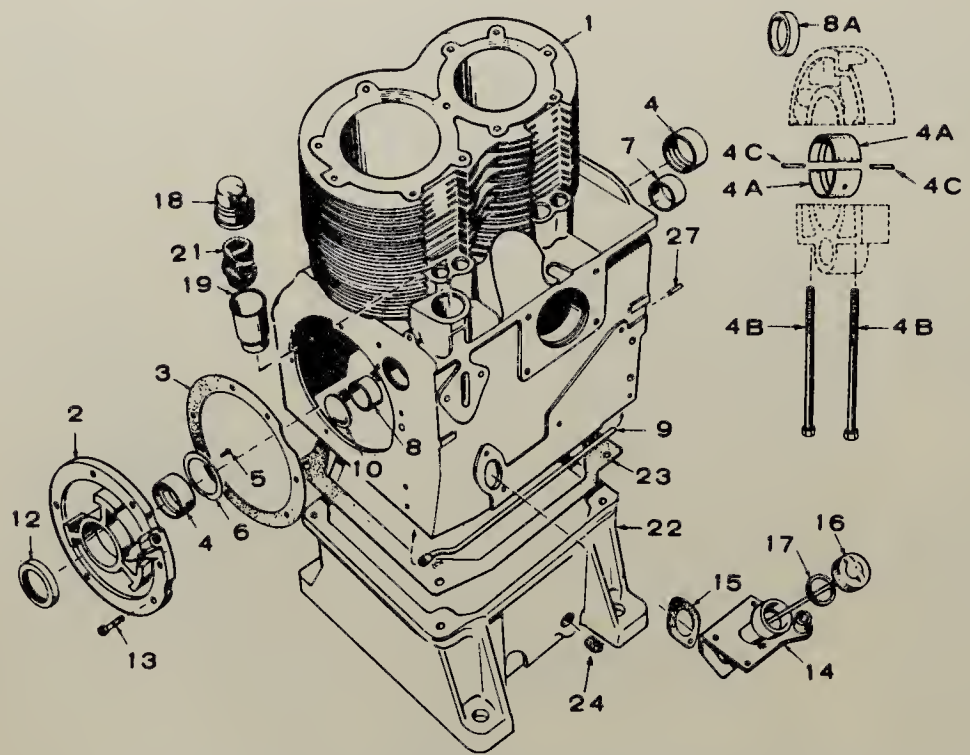
The crankshaft is supported in two lead-bronze sleeve bearings pressed into front of crankcase and rear bearing plate. Four-cylinder engines have an additional split center main bearing. Refer to Fig. O237.

To remove crankshaft, first remove oil pan, cylinder head, pistons and rods, flywheel and timing gear cover. Remove gear from front of crankshaft using a suitable puller. Remove rear bearing plate and center main bearing cap (four-cylinder engine). Withdraw crankshaft through rear opening in crankcase.

Crankshaft crankpin diameter is 2.0597-2.0605 inches (52.316-52.337 mm) and recommended connecting rod bearing clearance is 0.001-0.0033 inch (0.025-0.084 mm). Main journal diameter is 2.2437-2.2445 inches (56.99-57.01 mm) for Models DJA, DJB, DJBA, DJE, RDJE and RDJEA or 2.2427-2.2435 inches (56.965-56.985 mm) for Models DJC, RDJC and RDJF. Recommended main bearing clearance is as follows: All Models DJA, DJB and DJE and early Models RDJE and RDJEA should be 0.0014-0.0052 inch (0.036-0.132 mm). Early Models DJC, RDJC and RDJF should be 0.0024-0.0062 inch (0.061-0.157 mm). Late Model DJC should be 0.0024-0.0049 inch (0.061-0.124 mm). Late Model DJBA clearance is 0.0020-0.0033 inch (0.051-0.084 mm). Late Models RDJE and RDJEA should be 0.0030-0.0043 inch (0.076-0.109 mm). Late Model RDJF front and rear bearing clearance is 0.0030-0.0043 inch (0.076-0.109 mm) while center bearing is 0.0024-0.0052 inch (0.061-0.132 mm). Main and rod bearings are available in undersizes of 0.010, 0.020 and 0.030 inch (0.254, 0.508 and 0.762 mm) as well as standard size.

Crankshaft end play is controlled by rear bearing plate. To adjust end play, vary the thickness of gasket pack between rear bearing plate and crankcase until recommended end play of 0.010-0.015 inch (0.25-0.38 mm) is obtained. If more than 0.015 inch (0.38 mm) total gasket thickness is required, use a combination of gaskets and steel shims to avoid excessive gasket compression.

If crankpin journal must be resized, crankpin fillets must be shot peened to relieve metal stress. If facilities for shot



1. Block assy.
2. Bearing plate
3. Gasket
4. End main bearings
*4A. Center main bearing
*4B. Bolt, center main
*4C. Pin, center main
5. Thrust washer pin
6. Thrust washer
7. Cam bearing, front
8. Cam bearing, rear
*8.A Cam bearing, center
9. Oil tube
10. Camshaft plug
12. Crank seal, rear
13. Bearing plate bolt
14. Oil fill tube
15. Gasket
16. Cap & sleeve
17. Cap gasket
18. Breather tube cap
19. Breather tube
21. Baffle
22. Oil base
23. Gasket
24. Drain plug
27. Gear cover dowel
*Four-cylinder models only.

Fig. O237—Exploded view of crankcase and oil base assembly typical of this engine series. Model DJBA is shown.

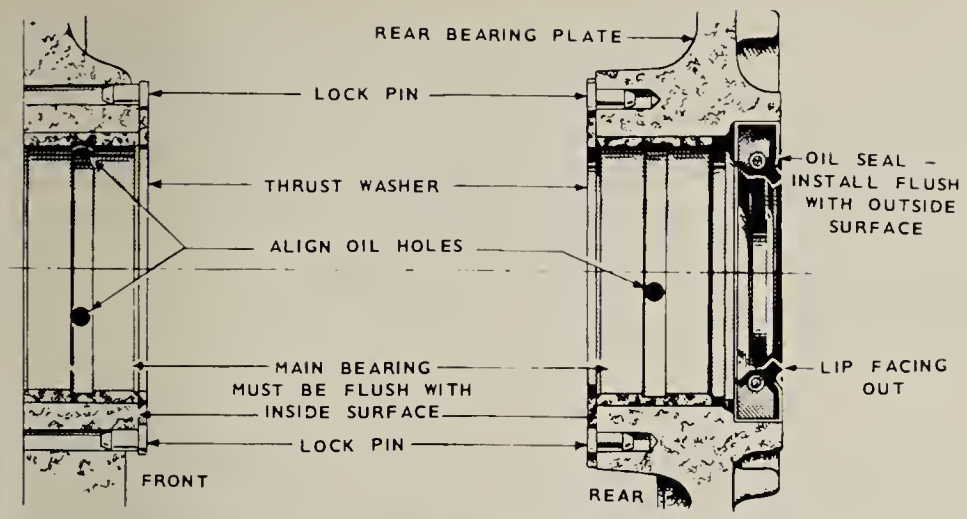


Fig. O238—Cross-sectional view of crankshaft main bearings to show proper installation. Note rear oil seal placement with open side of seal facing inward.

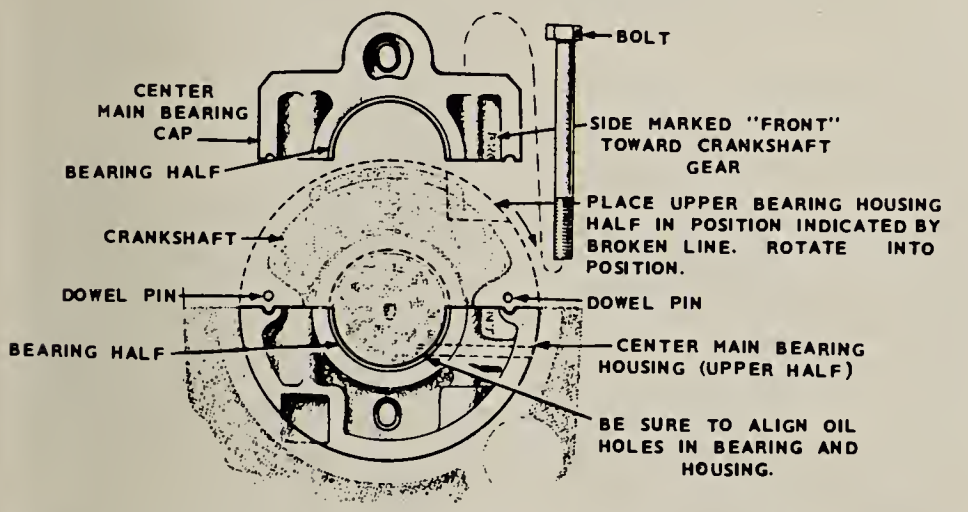

BOLT
CENTER MAIN BEARING CAP
BEARING HALF
SIDE MARKED "FRONT" TOWARD CRANKSHAFT GEAR
PLACE UPPER BEARING HOUSING HALF IN POSITION INDICATED BY BROKEN LINE. ROTATE INTO POSITION.
CRANKSHAFT
DOWEL PIN
DOWEL PIN
BEARING HALF
CENTER MAIN BEARING HOUSING (UPPER HALF)
BE SURE TO ALIGN OIL HOLES IN BEARING AND HOUSING.

Fig. O239—Installation of center main bearing used on four-cylinder engines. Refer to procedure in text.

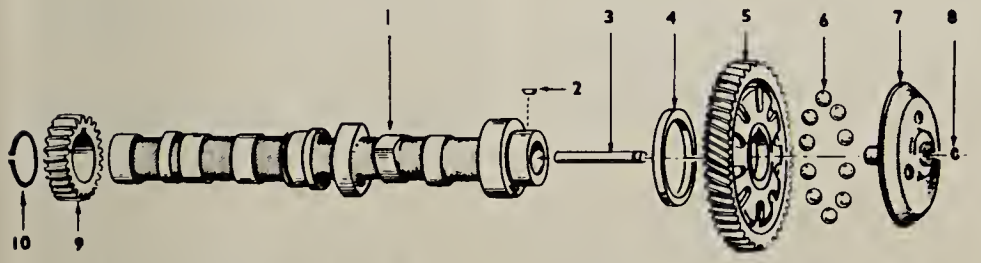


Fig. O240—Exploded view of camshaft and governor sensor assemblies. Model DJB is shown.

1. Camshaft
2. Cam gear key
3. Center pin
4. Thrust washer
5. Camshaft gear (incl. spacer.
6. Flyballs
7. Governor cap
8. Snap ring
9. Injection pump drive gear
10. Snap ring

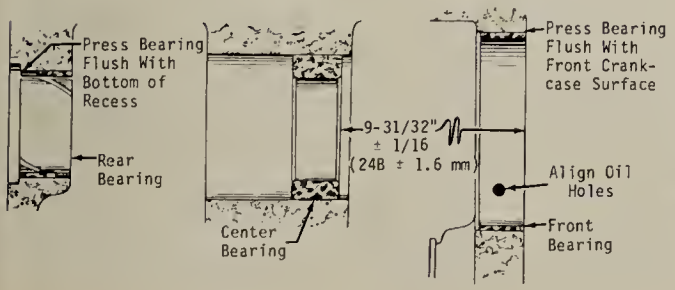

Press Bearing Flush With Bottom of Recess
Rear Bearing
Center Bearing
9-31/32" ± 1/16 (248 ± 1.6 mm)
Press Bearing Flush With Front Crankcase Surface
Align Oil Holes
Front Bearing

Fig. O241—Camshaft bushings should be pressed into crankcase as shown. Center bearing is used on four-cylinder models. Bushings are available in standard size only and do not require boring or reaming for proper fit.

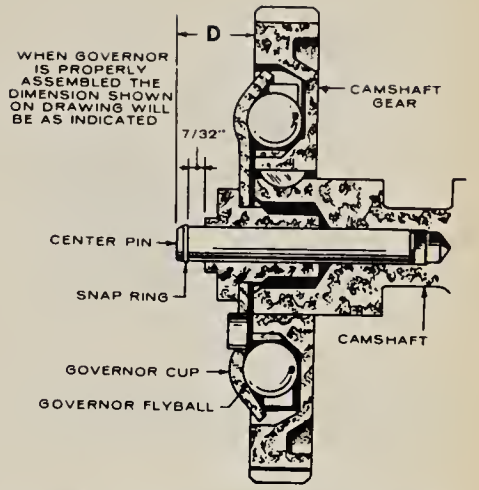


Fig. O242—Cross-sectional view of governor mechanism in camshaft gear. In order to limit governor cup movement of 7/32 inch (5.5 mm) as shown, dimension (D) must be 25/32 inch (19.8 mm) as described in text.

peening are not available, renew crankshaft instead of regrinding.

Front oil seal, located in gear cover, and rear oil seal, located in, rear bearing plate, may be renewed at this time. Be sure open side of seal faces inward and outer side of seal is flush with outer surface of front cover or rear plate. Lubricate seal lips with grease prior to reassembly.

When renewing main bearing inserts, press front and rear bearings into place as shown in Fig. O238. Make certain oil holes in bearings are aligned with holes in housing. Install thrust washers and lock pins. Tighten rear bearing plate mounting cap screws to a torque of 40-45 ft.-lbs. (54-61 N·m).

On four-cylinder engines, center main bearing is assembled after crankshaft is installed. Refer to Fig. O239. Rotate upper half into place making sure side marked "FRONT" faces front of crankshaft. Position dowel pins into grooves of bearing cap. Install bearing cap with lower bearing half and tighten cap screws to a torque of 97-102 ft.-lbs. (131-138 N·m).

Heat crankshaft gear to approximately 350°F (175°C). Align keyway in gear with crankshaft key, then drive gear into place. Be sure timing marks on crankshaft gear and camshaft gear are aligned (Fig. O243). Complete installation by reversing the removal procedure.

CAMSHAFT AND GOVERNOR

The camshaft gear is a press fit on shaft. The assembled unit must be removed from flywheel end of housing after removing flywheel, timing gear cover, injection pump and fuel lift pump.

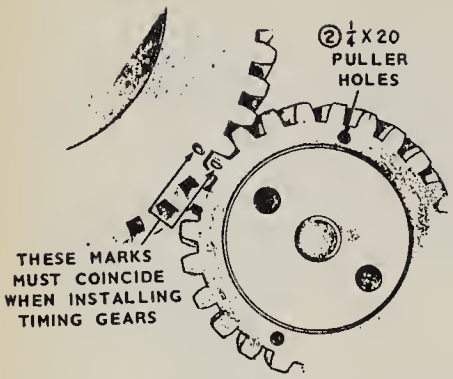


Fig. O243—Align crankshaft and camshaft timing marks as shown when installing camshaft.

Remove rocker arms and push rods, then lay cylinder block on its side to prevent tappets from dropping. Tappets cannot be withdrawn until after the camshaft is out.

Camshaft bushings are precision type which may be renewed as shown in Fig. O241 after camshaft is removed. If carefully installed, bushings do not require reaming or honing for proper fit. Recommended diametral clearance is 0.0015-0.0030 inch (0.038-0.076 mm) and maximum allowable clearance before renewal is 0.0037 inch (0.094 mm).

Governor weight unit is mounted on camshaft gear and governor cup rides on a center pin pressed into camshaft as shown in Fig. O242. Check the distance center pin extends from front face of camshaft gear. Distance (D) must be 25/32 inch (19.84 mm) as shown to give the proper travel to governor cup.

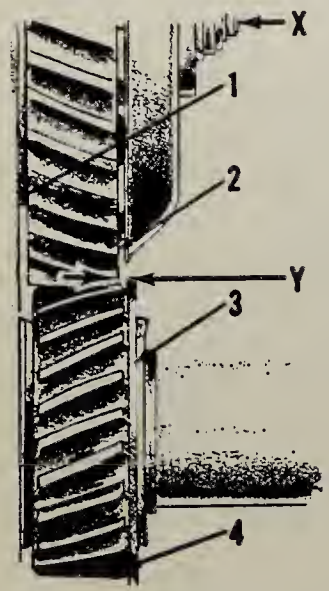


Fig. O244—Procedure to check camshaft gear end play. Refer to text.

X. Camshaft pushed in
Y. Measure end play here
1. Spacer washers
2. Camshaft gear
3. Crankshaft washer
4. Crankshaft gear

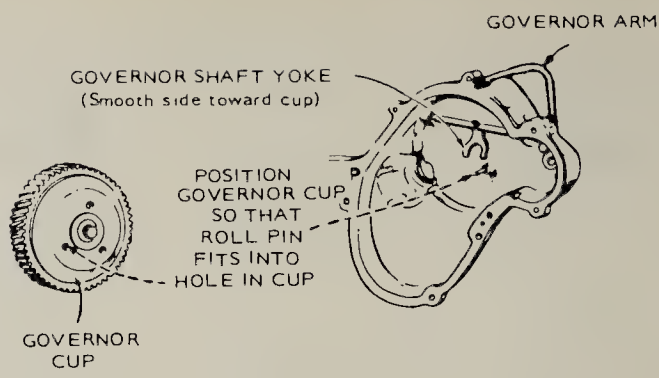


Fig. O245—Roll pin in timing gear cover must engage hole in governor cup.

Governor cup must be a free spinning fit on center pin. Renew the cup if race surface is grooved or rough, or if cup is excessively loose on center pin. Renew any flyballs if they have flat spots, grooves, or rust pitting. Center pin must be renewed if removed from camshaft for any reason.

When reinstalling the camshaft, align timing marks as shown in Fig. O243. Install crankshaft washer and snap ring, then check camshaft end play as shown in Fig. O244. Clearance (Y) should be 0.007-0.039 inch (0.18-0.99 mm) with camshaft pushed rearward and crankshaft pulled forward. If clearance is excessive, renew spacer washer (1) or crankshaft washer (3).

When renewing timing gear cover oil seal, drive old seal out inner side of cover. Using a suitable driver, install new seal until flush with outside surface of front cover. Be sure open side of seal faces inward. Lubricate seal lip prior to reassembly.

When reinstalling gear cover, be certain stop pin (Fig. O245) fits into one of the holes in governor cup. Tighten cap screws to a torque of 18-20 ft.-lbs. (24-27 N·m). Complete installation by reversing removal procedure. Bleed air from fuel system and check injection pump timing as outlined in MAINTENANCE section.

OIL PUMP

The engine is fully pressure lubricated and all oil is circulated through a full flow filter. Oil pressure should be 25 psi (172 kPa) or higher with engine at operating speed and temperature. A bypass valve is located in rear bearing plate. If oil pressure is too high or too low, inspect bypass valve plunger for sticking or wear.

The gear type oil pump is driven by crankshaft gear and is accessible after removing timing gear cover and oil base. Component parts of pump are not individually available. If pump is damaged or excessively worn, it must be renewed as a complete unit. Before installing pump, fill pump with oil to be sure it is primed. Tighten pump mounting cap screws to a torque of 15-20 ft.-lbs. (20-27 N·m) and oil base mounting screws to 45-50 ft.-lbs. (61-68 N·m).

FLYWHEEL

The flywheel is tapered fit on crankshaft. Use a suitable puller (such as ONAN tool 420-0100) to remove flywheel. When reinstalling, tighten retaining cap screw to a torque of 65-70 ft.-lbs. (90-95 N·m).

Replacement flywheel is supplied without timing markings. To accurately

Fig. O246—To accurately mark port closure point on a replacement flywheel, piston drop must be measured as outlined in text.

MODEL	PISTON DROP DIMENSION	PORT CLOSURE (BTDC)
DJA	0.102 in. (2.591 mm)	17°
DJB, DJBA, DJC (Prior to Spec P)	0.155 in. (3.937 mm)	21°
DJB, DJBA, DJC (Spec P and later)	0.128 in. (3.251 mm)	19°
DJE, RDJE, RDJEA	0.128 in. (3.251 mm)	19°
RDJF (prior to Spec P)	0.155 in. (3.937 mm)	21°
RDJF (Spec P and later)	0.128 in. (3.251 mm)	19°

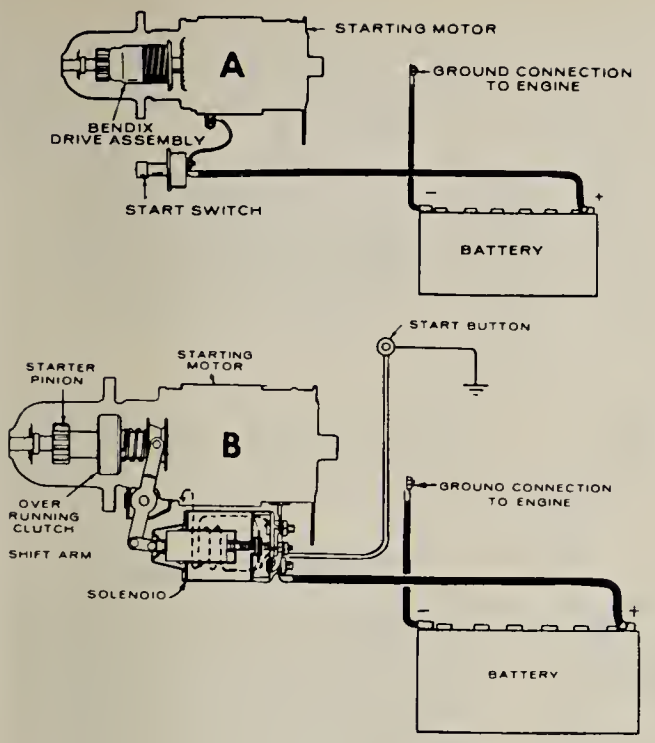


Fig. O247—Views of Bendix-drive starter and solenoid-shift starter in basic electric circuits. Refer to text.

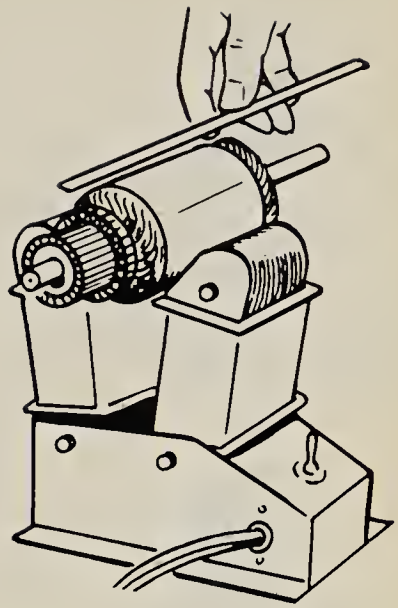


Fig. O248—Use of growler to check armature for short circuit. Follow procedure in text.

determine top dead center and port closing points and mark flywheel accordingly, number 1 piston travel must be measured with a depth gage. With cylinder head removed, rotate crankshaft until number 1 piston is at TDC of the compression stroke. Mark this point on the flywheel in line with timing pointer. Next, rotate flywheel counterclockwise until piston drops approximately 0.250 inch (0.6 mm). Then, rotate flywheel clockwise until piston is at its specified piston drop (port closure) dimension as listed in table shown in Fig. O246. Mark port closure (PC) point on flywheel.

Flywheel ring gear is renewable. To remove old ring gear, cut or grind part way through, then use a hammer and chisel to break gear. Heat new ring gear to about 400°F (200°C), then quickly install onto flywheel. Be sure gear bottoms squarely against flywheel shoulder.

NOTE: Do not heat ring gear with a torch as it may warp or heat treatment may be destroyed.

ELECTRIC STARTERS

Two styles of battery-driven electric starter motors are used. Bendix-drive starter shown at A–Fig. O247 is designed to engage teeth of flywheel ring gear when starter switch is depressed to close circuit causing starter motor to turn. Engagement of starter pinion with ring gear by means of spiral shaft screw within Bendix pinion is cushioned by action of its coiled drive spring so starting motor can absorb the sudden loading shock of engagement. Engine manufacturer recommends that complete Bendix drive unit be renewed in case of failure, however, if a decision is made to overhaul starter drive by obtaining parts from manufacturer of the starter (Prestolite), be sure that correct drive spring is used. Length of spring is critical to mesh and engagement of starter pinion to flywheel ring gear. There are no procedures for adjustment of this starter.

Service is generally limited to cleaning and careful lubrication, renewal of starting motor brushes (4 used), brush tension springs and starter motor and drive housing bearings. Refer to STARTER MOTOR TESTS for electrical check-out procedures for starter armature and field windings.

Solenoid-shift style starter (B–Fig. O247) uses a coil solenoid to shift starter pinion into mesh with flywheel ring gear and an overrunning (one-way) clutch to ease disengagement of pinion from flywheel as engine starts and runs.

NOTE: Starter clutch will burn out if held in contact with flywheel for overlong periods. Starter switch must be released quickly as engine starts.

All parts of stater are available for service. Solenoid unit and starter clutch are renewed as complete assemblies.

STARTER MOTOR TESTS

ARMATURE SHORT CIRCUIT. Place aramature in growler as shown in Fig. O248 and hold a hack saw blade or similar piece of thin steel stock above and parallel to core. Turn growler "ON". A short circuit is indicated by vibration of blade and attraction to core. If this condition appears, renew armature.

GROUNDED ARMATURE. Check each segment of commutator for grounding to shaft (or core) using ohmeter setup as shown in Fig. O249. A low Rx1 scale) continuity reading indicates that armature is grounded and renewal is necessary.

It is good procedure to mount armature on a test bench or between lathe centers to check for runout of commutator or shaft. If shaft is worn badly, renewal is recommended. If commutator runout exceeds 0.004 inch (0.10 mm), reface by turning.

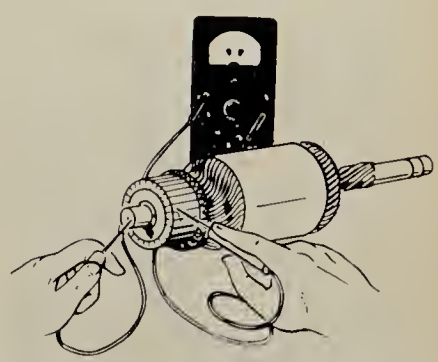


Fig. O249—Test for grounded armature commutator by placing ohmmeter test probes a shown. Probe shown touching shaft may also be held against core. Refer to text.

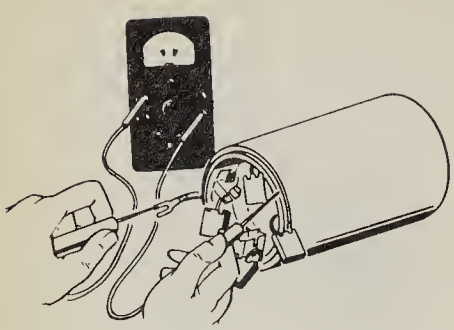


Fig. O250—Use ohmmeter as shown to check field coil for suspected internal grounding.

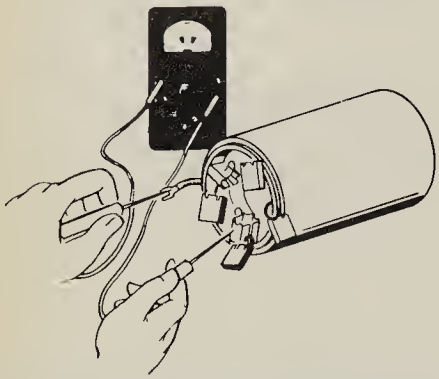


Fig. O251—Ohmmeter used to check for breaks or opens in field coil windings. Be sure to check lead wires.

GROUNDED FIELD COILS. Refer to Fig. O250 and touch one ohmmeter probe to a clean, unpainted spot on frame and the other to connector as shown after unsoldering field coil shunt wire. A low range reading (Rx1 scale) indicates grounded coil winding. Be sure to check for possible grounding at connector lead which can be corrected, while grounded field coil cannot be repaired and calls for renewal.

OPEN IN FIELD COILS. Use procedure shown in Fig. O251 and check all four brush holders for continuity. If there is no continuity or if a high resistance reading appears, renewal is necessary.

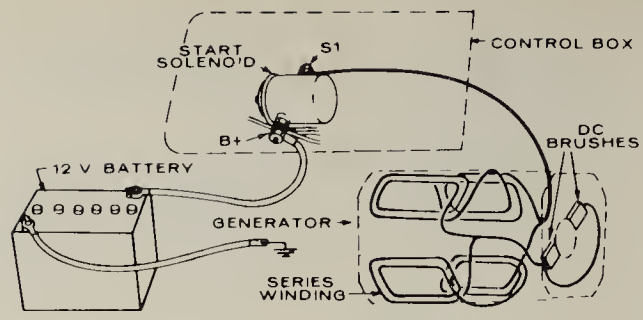
EXCITER CRANKING

Exciter cranking, with cranking torque furnished by switching battery current through a separate series winding of generator field coils and the brushes using dc portion of generator armature is wired as shown in Fig. O252.

This starting procedure may be used on Model DJA. In cases where exciter cranking is inoperative, due to battery failure or other cause, unit may be started by use of a manual rope starter. In some cases, a recoil type "Readi-Pull" starter may be furnished for standby use.

In case exciter cranking system will not operate, isolate starter solenoid switch and battery from dc field windings and perform a routine continuity check of all components by use of a volt-ohmmeter. Refer to Fig. O252 for possible test points. If problem does not become apparent as caused by battery (low voltage), defective starter solenoid

Fig. O252—Schematic of dc circuit portion of ac generator used for exciter cranking. Refer to text.



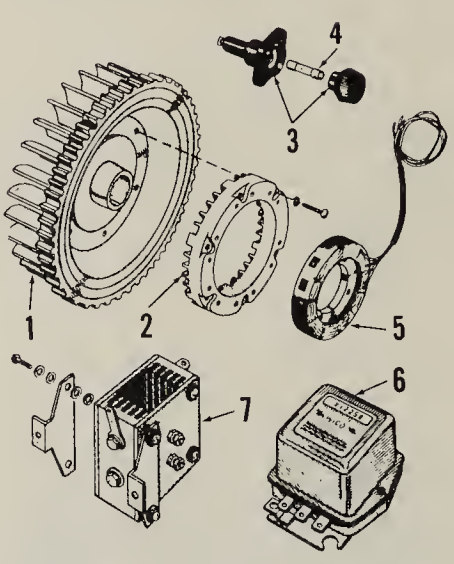


Fig. O253—Typical flywheel alternator shown in exploded view. In some models, regulator (6) and rectifier (7) are combined in a single unit.

1. Flywheel
2. Rotor
3. Fuse holder
4. Fuse (20A)
5. Stator & leads
6. Regulator, 2-step
7. Rectifier assy.

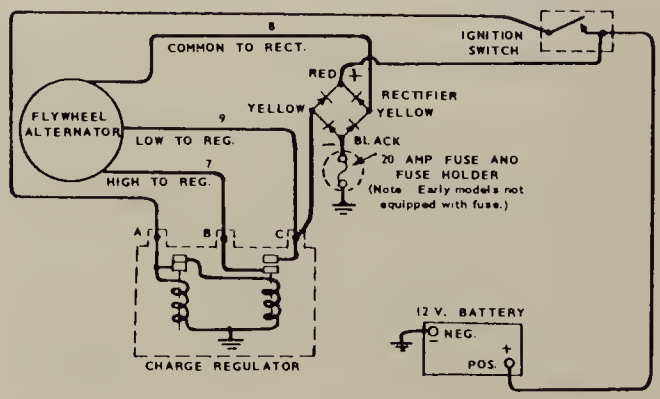
short or open circuit in lead wires or dc brushes, it will be necessary to check out generator in detail and may involve factory service.

FLYWHEEL ALTERNATOR

This battery charging system is simple and basically trouble-free. Flywheel-mounted permanent magnet rotor provides a rotating magnetic field to induce ac voltage in fixed stator coils. Current is then routed through a two-step mechanical regulator to a full-wave rectifier which converts this regulated alternating current to direct current for battery charging. Late models are equipped with a fuse between negative (−) side of rectifier and ground to protect rectifier from accidential reversal of battery polarity. Refer to schematic, Fig. O254. Maintenance services are limited to keeping components clean and ensuring that wire connections are secure.

TESTING. Check alternator output by connecting an ammeter in series between the positive (+), red terminal of rectifier and ignition switch. Refer to Fig. O254. At 1800 engine rpm), a discharged battery should cause about 8 amps to register on the ammeter. As battery charge builds up, current should decrease. Regulator will switch from high charge to low charge at about 14½ volts with low charge current of about 2 amps. Switch from low charge to high

Fig. O254—Schematic of flywheel alternator circuits for location of test and check points. Refer to text for procedures.



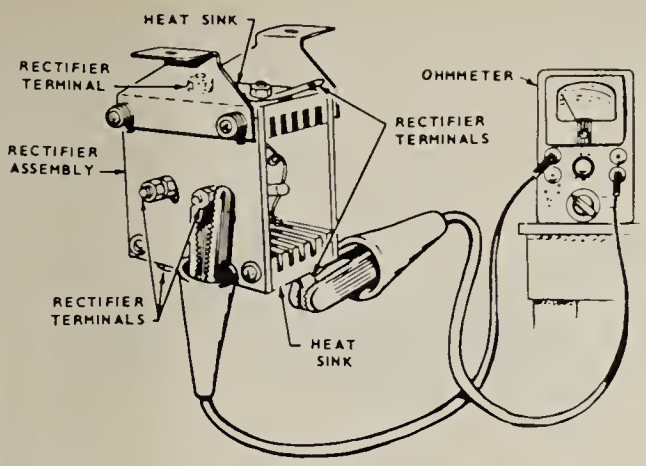


Fig. O255—Test each of four diodes in rectifier using volt-ohmmeter hook-up as shown. Refer to text for procedure.

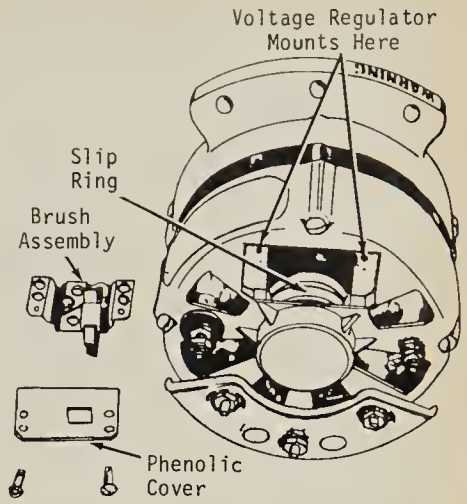


Fig. O256—View of optional belt driven, external alternator used on some models.

charge occurs at about 13 volts. If output is inadequate, test as follows:

Check rotor magnetism with a piece of steel. Attraction should be strong.

Check stator for grounds after disconnecting by grounding each of the three leads through a 12-volt test lamp. If grounding is indicated by lighted test lamp, renew stator assembly.

To check stator for shorts or open circuits, use an ohmmeter of proper scale connected across open leads to check for correct resistance values. Identify leads by reference to schematic.

From lead 7 to lead 8 . . . . . 0.25 ohms
From lead 8 to lead 9 . . . . . 0.95 ohms
From lead 9 to lead 7 . . . . . 1.10 ohms

Variance by over 25 percent from these values calls for renewal of stator.

RECTIFIER TESTS. Use an ohmmeter connected across a pair of terminals as shown in Fig. O255. All rectifier leads should be disconnected when testing. Check directional resistance through each of the four diodes by comparing resistance reading when test leads are reversed. One reading should be much higher than the other.

NOTE: Forward-backward ratio of a diode is on the order of several hundred ohms.

If a 12 volt test lamp is used instead of an ohmmeter, bulb should light, but dimly. Full bright or no light at all indicates that diode being tested is defective.

Voltage regulator may be checked for high charge rate by installing a jumper lead across regulator terminals (B and C – Fig. O254). With engine running, battery charge rate should be about 8 amps. If charge rate is low, then alternator or its wiring is defective.

If charge rate is correct (near 8 amps), defective regulator or its power circuit is indicated. To check, use a 12 volt test lamp to check input at regulator terminal (A). If lamp lights, showing adequate input, regulator is defective and should be renewed.

NOTE: Regulator, being mechanical, is sensitive to vibration. Be sure to mount it on bulkhead or firewall separate from engine for protection from shock and pulsating action.

Engine should not be run with battery disconnected, however, this alternator system will not be damaged if battery terminal should be accidentally separated from binding post.

BELT DRIVEN ALTERNATOR

An optional belt driven, battery charging, external alternator may be used on some models. Refer to Fig. O256. Normal alternator output voltage is 13.8 to 14.8 volts. If alternator output is not within specifications, perform regulator test as follows: With engine running, connect a jumper wire from positive output post on alternator to field post and recheck alternator output. If voltage reading is now within specifications or higher, regulator is defective. Voltage regulator and brush assembly may be renewed without disassembling alternator.

Before disassembling alternator, place a scribe mark across end frame and front cover to provide proper alignment when reassembling. Check stator and rotor windings for open or grounded circuits. Diodes should have continuity in one direction only. Renew faulty components or alternator assembly as required.

CLUTCH

When optional Rockford clutches are furnished with these engines, an adapter flange is fitted to engine output shaft for mounting clutch unit and a variety of housings are used dependent upon application and model of engine or clutch used. Refer to Fig. O257 for guidance in adjustment and proceed as follows:

Remove plate from top of housing and rotate engine manually until lock screw (1 – Fig. O257) is at top of ring (2) as shown. Loosen lock screw and turn adjusting ring clockwise (as facing through clutch toward engine) until toggles cannot be locked over center. Then, turn ring in reverse direction until toggles can just be locked over center by a very firm pull on operating lever. If a new clutch plate has been installed, slip under load to knock off "fuzz" and readjust. Lubricate according to instructions on unit plate.

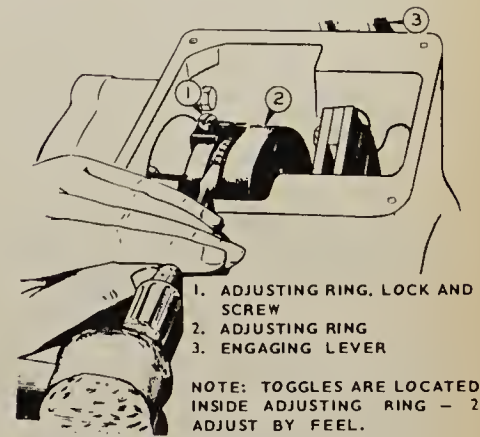


Fig. O257—Procedure for adjustment of Rockford clutch. Refer to text.

REDUCTION GEAR ASSEMBLIES

Typical reduction gear unit is shown in Fig. O258. Ratio of 1:4 is common in industrial applications. Lubrication calls for use of SAE 50 weight motor oil or SAE 90 gear oil. Refer to instructions printed on gear case for guidance. In most cases, a total of six plugs are fitted into case for lubricant fill or level check. Plug openings to be used are determined by positioning of gearbox in relation to horizontal or vertical. It is recommended that square plug heads be cut off those plugs not to be used to fill, check or drain so as to eliminate chance of error by overfill or underfill. All parts shown are available for renewal if needed in overhaul.

NOTE: In some installations, no shaft seal is fitted between engine crankcase and reduction gear housing. In these cases, with a common oil supply, engine oil lubricates gears and bearings of reduction gear unit and gear oil is not used. Be sure to check nameplate or operator's manual.

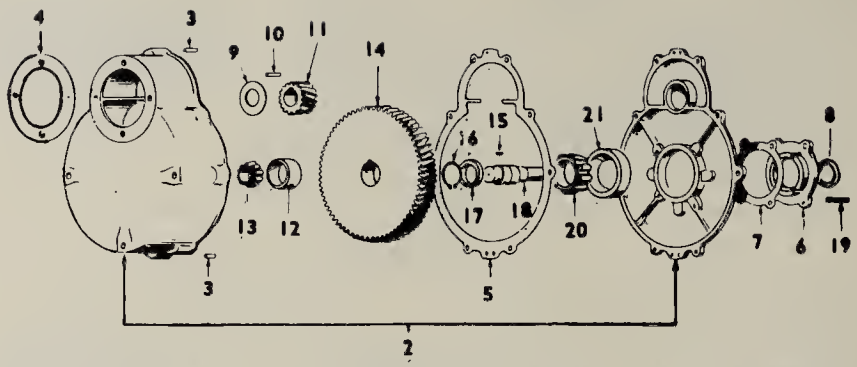


Fig. O258—Exploded view of typical reduction gear set. Refer to text for service details.

2. Housing & cover
3. Dowel pins (2)
4. Gasket (engine)
5. Cover gasket
6. Bearing retainer
7. Shims
8. Oil seal
9. Pinion washer
10. Pinion key
11. Pinion gear
12. Bearing cup
13. Bearing cone
14. Driven gear
15. Gear key
16. Snap ring
17. Bearing spacer
18. Shaft
19. Key
20. Bearing cone
21. Bearing cup

ONAN

Model	No. Cyls.	Bore	Stroke	Displ.
L317	3	89 mm (3.50 in.)	92 mm (3.62 in.)	1700cc (105 cu. in.)
L423	4	89 mm (3.50 in.)	92 mm (3.62 in.)	2300 cc 140 cu. in.)

Engines covered in this section are four-stroke liquid-cooled diesel engines. All models are equipped with a 12 volt electric starting motor. Crankshaft rotation is counterclockwise when viewed from the rear (flywheel end) of engine.

OPERATION

PREHEATING AND STARTING. When engine is cold and air temperature is below 21°C (70°F), engine glow plugs must be preheated to aid in starting.

CAUTION: Do not use ether as a starting aid. Heat from glow plugs could ignite ether vapor causing an explosion resulting in severe engine damage.

If engine is equipped with a preheat indicator light, engine is ready for starting when preheat light goes out. If not equipped with a preheat indicator light, energize glow plug circuit as indicated in the following table.

Ambient Temperature	Preheat Time
Above 21°C (70°F)	10-20 seconds
– 18°C to 21°C (0°-70°F)	25-35 seconds
Below – 18°C (0°F)	30-45 seconds

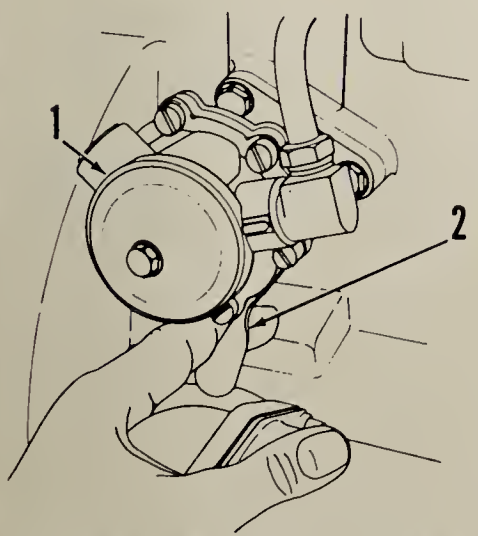


Fig. O300—Fuel transfer pump (1) is located at right rear side of engine. Transfer pump is equipped with a priming lever (2) which may be manually operated when bleeding air from fuel system.

If engines fails to start after 30 seconds of cranking, wait two minutes before repeating preheat and starting procedure.

MAINTENANCE

LUBRICATION

Recommended engine oil is API service classification CD/SF or CD/SE. The following SAE viscosity grades are recommended: SAE 10W for temperatures below 0°F (32°F), SAE 20W-20 for temperatures between – 10°C (15°F) and 15°C (60°F) or SAE 30W or SAE 15W-40 if temperature range will be consistently above 0°C (32°F).

Recommended oil change interval is after every 100 hours of operation. Spin on type oil filter should be renewed at each oil change interval. Oil should be drained with engine at operating temperature. Crankcase capacity is approximately 5.7 L (6 quarts) with filter change. Do not overfill.

FUEL SYSTEM

A good quality Number 2 diesel fuel is recommended for most conditions. For cold weather operation, Number 1 fuel or a blend of Number 1 and Number 2 fuel may be used. All fuel must have a minimum Cetane number of 40 to ensure satisfactory engine performance.

NOTE: It is extremely important that fuel be kept clean and free of water. Due to precise tolerances of diesel injection components, dirt and water in the system can cause severe damage to injection pump and injection nozzles.

FUEL FILTER. The fuel filter is mounted on right side of engine. Fuel filter renewal interval is more dependent upon fuel quality and cleanliness than length of service or operating conditions. If engine indicates signs of fuel starvation (loss of power or surging), fuel filter should be renewed. Manufacturer also recommends renewing fuel filter yearly regardless of hours of operation or engine performance.

To renew filter, shut off fuel supply. Thoroughly clean filter and surrounding area. Release filter retaining clips and remove filter element. Install new filter element and secure with retaining clips. Bleed air from system as outlined in the following paragraph.

BLEED FUEL SYSTEM. To bleed air from fuel system, loosen fuel inlet line fitting at the injection pump. Actuate fuel transfer pump priming lever (2–Fig. 0300) until air-free fuel flows from fitting, then retighten fitting.

NOTE: If camshaft lobe which drives transfer pump is at full lift position, priming lever cannot be operated. Rotate crankshaft one revolution to reposition camshaft lobe.

If engine fails to start after bleeding low pressure portion of fuel system, it will be necessary to bleed injector high pressure lines. Loosen high pressure line fitting at each injector. With stop control in "Run" position and throttle in high speed position, crank engine with starter motor until fuel is discharged from each injector line. Do not operate starter motor longer than 30 seconds at a time to prevent overheating. Tighten injector line fittings and start engine.

CAUTION: Do not use ether as a starting aid as glow plugs could ignite ether vapor causing an explosion resulting in severe engine damage.

ENGINE SPEED ADJUSTMENT. To check engine speed, first run engine until operating temperature is obtained. Move throttle control to low idle position and high idle position making sure injec-

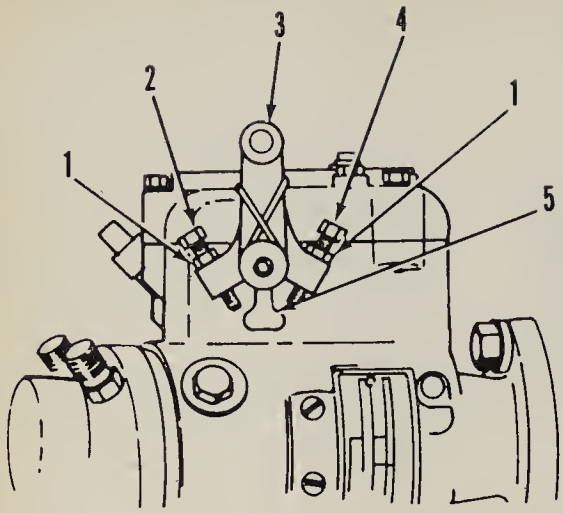


Fig. O301—View of injection pump control lever and speed adjustment points.
1. Locknut
2. High idle adjusting screw
3. Speed control lever
4. Low idle adjusting screw
5. Lever stop

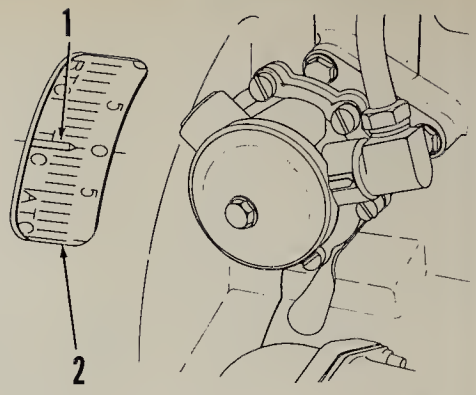


Fig. O303—Engine timing marks are located on flywheel. Remove timing window cover from flywheel housing to observe timing marks and pointer (1) through timing window (2).

tion pump control lever (3–Fig. O301) contacts low idle and high idle stop screws. Low idle speed should be within the range of 755 to 825 rpm depending upon engine application. High idle speed (no-load) should be 7 to 10 percent greater than speed stamped on pump name plate on variable speed applications or 3 to 4.5 percent greater on fixed rpm applications.

NOTE: Adjustments made by non-qualified personnel which alter exhaust emission control settings may violate Federal, state and/or local regulations. Manufacturer's warranty on injection pump and engine may also be voided by unauthorized adjustments to injection pump.

To adjust engine speed setttings, disconnect throttle control from pump control lever (3–Fig. O301). With engine running, push speed control lever forward until low idle adjusting screw (4) contacts lever stop (5). Turn screw in to increase speed or out to decrease speed. Hold adjusting screw and tighten locknut to secure adjustment. Move control lever rearward until high idle adjusting screw (2) contacts stop. Turn adjusting screw out to increase speed or in to decrease speed. After specified speed setting is obtained, hold adjusting screw and tighten locknute. Be sure to install a new seal wire on high speed adjusting screw.

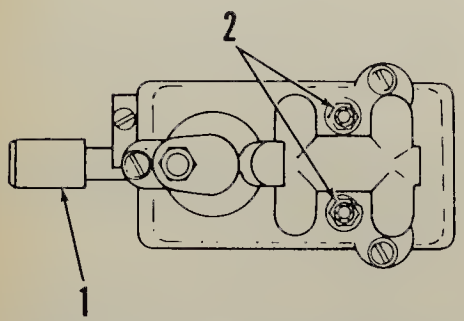


Fig. O302—Speed droop adjusting screw (1) is used to adjust governor sensitivity on fixed rpm engine applications. Electric fuel solenoid terminals are located at (2).

SPEED DROOP ADJUSTMENT. Injection pumps used on fixed rpm (generator) applications are equipped with an external speed droop adjusting screw (1–Fig. O302). The droop screw, located at rear of injection pump housing, varies governor sensitivity by changing governor spring rate. Turning adjusting screw in makes governor regulation less sensitive and turning droop screw out increases governor sensitivity to changing engine loads. Droop screw adjustment will affect both full-load and no-load settings and may require readjustment of high speed stop screw as previously outlined. After each adjustment of screw, engine must be shut off briefly to allow governor spring to unload before making another adjustment. Be sure to install new seal wires after adjustment is completed.

PUMP STATIC TIMING. To check injection pump to engine static timing, first shut off fuel supply. Thoroughly clean outside of pump. Place a pan beneath fuel pump to catch fuel, then remove timing window cover from side of pump (Fig. O304). Remove timing window cover from side of flywheel housing (Fig. O303). Turn crankshaft in normal direction of rotation until number one piston is coming up on compression stroke. Continue to slowly turn crankshaft until timing pointer in flywheel housing is aligned with specified degree mark on flywheel. (Specified static timing is stamped on engine model plate.) At this point, pump timing marks (visible through timing window) on cam ring and governor weight retainer should be aligned as shown in Fig. O304.

If pump timing marks are not aligned, loosen pump mounting stud nuts and rotate injection pump until timing marks are aligned. Tighten pump stud nuts. Turn crankshaft back (clockwise viewed from rear) about ½ revolution, then turn crankshaft in normal direction until specified timing mark on flywheel is aligned with pointer again and recheck pump timing mark alignment. Reinstall pump timing window cover and bleed air from system if necessary.

COOLING SYSTEM

All engines are liquid-cooled using a belt driven water pump to circulate coolant through the engine block and radiator or heat exchanger. Either one or two thermostats may be used, depending upon engine cooling requirements, to regulate engine operating temperature. A high temperature cut-off switch senses coolant temperature

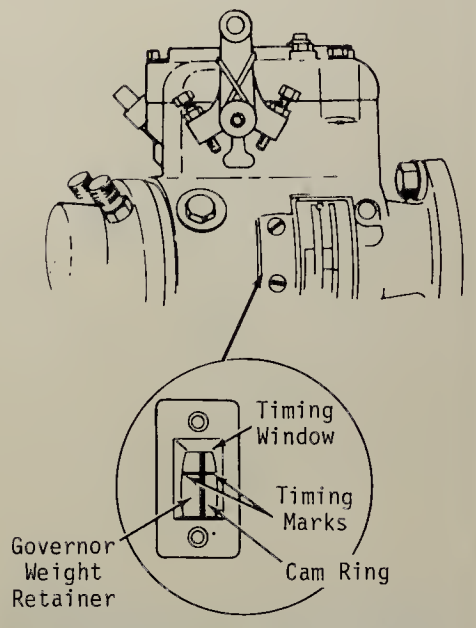


Fig. O304—Injection pump timing marks are located under timing window cover on side of pump housing.

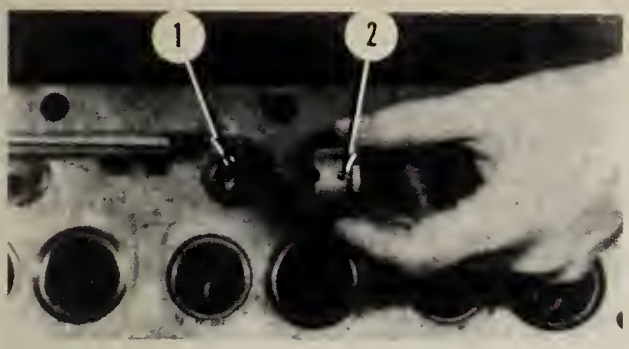


Fig. O305—When reinstalling hot plugs in cylinder head, align guide (2) on plug with slot (1) in cylinder head bore.

and shuts off engine if operating temperature exceeds a safe limit. Examine cooling system to determine cause if cut-off switch is activated.

Manufacturer recommends cleaning and flushing cooling system, including the engine block, every two years or 3000 hours of operation. A mixture of ethylene glycol antifreeze should be used as an engine coolant even when freezing temperatures are not expected. In addition to lowering the freezing point of water, antifreeze contains additives which prevent rust and corrosion of cooling system components. Antifreeze solution should be renewed yearly. Maintain coolant level approximately one inch below filler opening.

REPAIRS

TIGHTENING TORQUES

Refer to the following table for engine assembly torques. Fastener threads must be clean and lubricated with engine oil before torquing.

Connecting rod	85 N·m (63 ft.-lbs.)
Cylinder head	123 N·m (90 ft.-lbs.)
Flywheel	68 N·m (50 ft.-lbs.)
Front pulley	133 N·m (98 ft.-lbs.)
Glow Plug	19 N·m (14 ft.-lbs.)
Injection pump gear	52 N·m (38 ft.-lbs.)
Injector nozzle	69 N·m (51 ft.-lbs.)
Main bearing cap	123 N·m (90 ft.-lbs.)
Rocker arm cover	18 N·m (13 ft.-lbs.)
Rocker arm studs	52 N·m (39 ft.-lbs.)

CYLINDER HEAD

To remove cylinder head, first drain cooling system and disconnect battery ground cable. Remove components such as muffler, air cleaner and shrouds as necessary to gain access to cylinder head. Remove fan and water pump assembly. Disconnect and remove high pressure fuel lines and fuel return lines from injectors. Disconnect wiring to glow plugs. Unbolt and remove intake and exhaust manifolds. Remove rocker arm cover. Disconnect and remove rocker arm oiling tube. Remove rocker arms and push rods keeping all parts in order so they can be reinstalled in their original positions. Remove cylinder head mounting cap screws and lift off cylinder head.

Thoroughly clean cylinder head and block, then inspect for cracks, warpage or other damage. If warped, a maximum of 0.25 mm (0.010 inch) of material may be removed from cylinder head and 0.05 mm (0.002 inch) may be removed from cylinder block to true mating surfaces. If warped beyond these limits, components must be renewed. Inspect hot plugs (Fig. O305) for damage (hairline cracks are normal and acceptable) or erosion and renew if necessary. When installing hot plug, be sure to align guide on hot plug with groove in cylinder head. Hot plug must not protrude more than 0.065 mm (0..026 inch) beyond cylinder head surface or be recessed more than 0.25 mm (0.001 inch) below surface of head. If hot plug is loose in its bore, remove plug and coat outer surface with Loctite 325 before reinstalling.

When reinstalling cylinder head, be sure cap screw holes in cylinder block are free of dirt, corrosion or an excessive amount of oil or water which would interfere with proper tightening of cap screws. Machined surfaces of cylinder head and block must be thoroughly clean. Do not use any sealer or gasket cement on head gasket or mounting surfaces. Be sure gasket is installed with side upward as marked on gasket. Apply light coat of engine oil to cap screw threads, then tighten gradually in steps following appropriate tightening sequence shown in Fig. O306 or O307. Final tightening torque is 123 N·m (90 ft.-lbs.) for all models. Reinstall push rods and rocker arms in their original positions. Lubricate threads of rocker arm locknuts. A minimum torque of 3.4 N·m (30 in.-lbs.) should be required to turn locknuts. If less torque is required, nut must be renewed. A new locknut should require a minimum of 6.2 N·m (55 ft.-lbs.) initial torque to turn.

NOTE: Do not use air wrench to remove or reinstall rocker arm locknuts as self-locking threads will be damaged.

Adjust valve clearance as outlined in the following paragraph. Install new in-

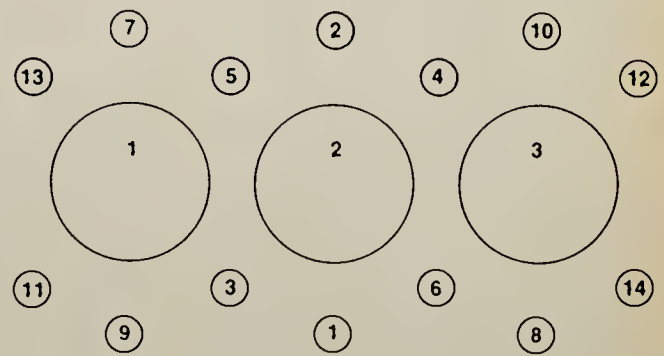


Fig. O306—Follow sequence shown when tightening cylinder head cap screws on Model L317.

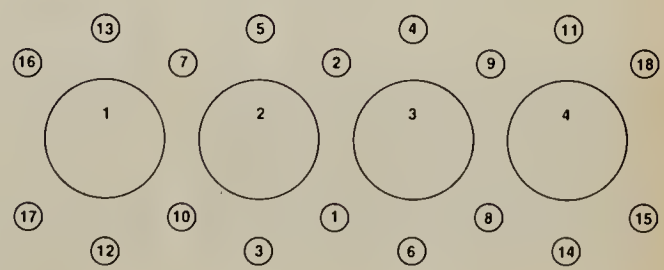


Fig. O307—When tightening cylinder head cap screws, follow tightening sequence shown for Model L423.

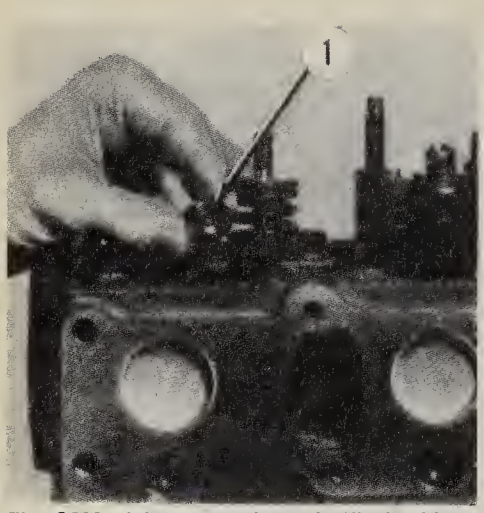


Fig. O308—Injector nozzle seals (1) should be renewed whenever injectors are removed. Be sure seals are installed with concave side facing down.

jection nozzle seals into nozzle bore with concave (inward curve) side facing down (Fig. O308).

NOTE: Incorrect installation of nozzle seals will cause nozzles to overheat and possibly stick. Do not attempt to reuse nozzle seals.

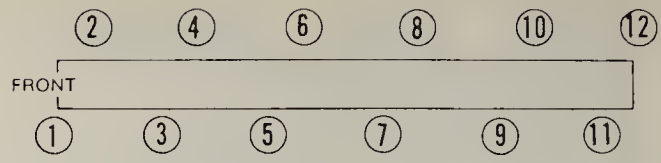
Tighten rocker cover mounting nuts to a torque of 18 N·m (13 ft.-lbs.). Tighten intake manifold cap screws to a torque of 23 N·m (17 ft.-lbs.). Tighten exhaust manifold cap screws evenly following the tightening sequence shown in Fig. O309. Final torque for cap screws with flatwashers is 28 N·m (21 ft.-lbs.) and for flange head cap screws is 35 N·m (26 ft.-lbs.). After completing initial tightening sequence, repeat tightening sequence to ensure all cap screws are at specified torque. Exhaust manifold cap screws should be retorqued after two hours of operation. Complete installation by reversing the removal procedure.

VALVE CLEARANCE ADJUSTMENT

Clearance between rocker arm and end of valve stem should be 0.20 mm (0.008 inch) for intake valves and 0.30 mm (0.012 inch) for exhaust valves with engine cold. Valve clearance is adjusted by turning rocker arm stud locknut while inserting a feeler gage of proper thickness between rocker arm and valve stem.

NOTE: A minimum torque of 3.4 N·m (30 in.-lbs.) should be required to start turning rocker arm locknut with threads oiled. Renew locknuts which do not meet minimum requirements. A new locknut with threads oiled should require a minimum initial torque of 6.2 N·m (55 in.-lbs.) to turn nut.

Fig. O309—Exhaust manifold mounting cap screws should be tightened evenly following the sequence shown. Tightening procedure should be performed twice to ensure all cap screws are at specified torque.



Adjust valves of each cylinder in regular engine firing order with piston at TDC on compression stroke. Firing order is 1-3-2 on Model L317 and 1-2-4-3 on Model L423.

On Model L317, turn crankshaft in normal direction of rotation until number 1 piston is at TDC on compression stroke (both rocker arms should be loose). Adjust intake and exhaust valve clearance as specified. Rotate crankshaft 240° (⅔ revolution) and adjust valves for number 3 cylinder. Turn crankshaft an additional 240° and adjust valves for number 2 cylinder.

On Model L423, turn crankshaft in normal direction of rotation until number 1 piston is at TDC on compression stroke (both rocker arms should be loose). Adjust intake and exhaust valves for number 1 cylinder as specified. Rotate crankshaft 180° (½ turn) and adjust valves for number 2 cylinder. Repeat procedure for cylinders 4 and 3.

VALVE SYSTEM

Valve face angles are 29° for intake and 44° for exhaust valves. Valve seat angles are 30° for intake and 45° for exhaust. Manufacturer recommends against handlapping which could destroy the interference angle seating surface. Width of valve seats should be 0.88-2.30 mm (1/32-3/32 inch). Depth of valve head below cylinder head surface should be 0.48-1.13 mm (0.019-0.044 inch) for intake valves and 0.67-1.33 mm (0.026-0.052 inch) for exhaust valves. If depth is less than specified, grind seat to obtain desired depth. If depth exceeds 2.13 mm (0.084 inch) on intake or 2.33 mm (0.092 inch) on exhaust, install new valve seat insert.

Hardened valve seat inserts are standard for exhaust valve seats. Seat inserts are also available through service parts for intake seats. Cylinder head must be machined to accept intake seat inserts. Oversize inserts are also available for both exhaust and intake. Refer to the chart in Fig. O310 for seat insert dimensions and corresponding counterbore dimensions required in cylinder head.

Valve stem diameter for all valves should be 7.93-7.95 mm (0.312-0.313 inch). Clearance between valve stem and guide should be 0.04-0.08 mm (0.002-0.003 inch), If clearance exceeds 0.16 mm (0.006 inch), valve guide and/or valve should be renewed. Valve guides may be renewed by pressing old guide out through bottom of cylinder head. Use appropriate valve guide driver to avoid damaging guides during pressing

VALVE SEAT INSERT	INSERT O.D.	COUNTERBORE O.D.	COUNTERBORE DEPTH
Exhaust - Standard	37.00-37.03mm (1.4567-1.4578in.)	36.93-36.95mm (1.4539-1.4547in.)	8.49-8.59mm (0.334-0.338in.)
Oversize 0.25mm	37.25-37.28mm (1.4665-1.4677in.)	37.18-37.20mm (1.4638-1.4645in.)	8.49-8.59mm (0.334-0.338in.)
0.50mm	37.50-37.53mm (1.4764-1.4775in.)	37.43-37.45mm (1.4736-1.4744in.)	8.49-8.59mm (0.334-0.338in.)
Intake - Standard	40.37-40.40mm (1.5894-1.5905in.)	40.30-40.32mm (1.5866-1.5874in.)	8.40-8.50mm (0.331-0.334in.)
Oversize 0.25mm	40.62-40.65mm (1.5992-1.6004in.)	40.55-40.57mm (1.5965-1.5972in.)	8.40-8.50mm (0.331-0.334in.)
0.50mm	40.87-40.90mm (1.6091-1.6102in.)	40.80-40.82mm (1.6063-1.6070in.)	8.40-8.50mm (0.331-0.334in.)

Fig. O310—Chart shows cylinder head counterbore machining specifications for installation of standard and oversize valve seat inserts.

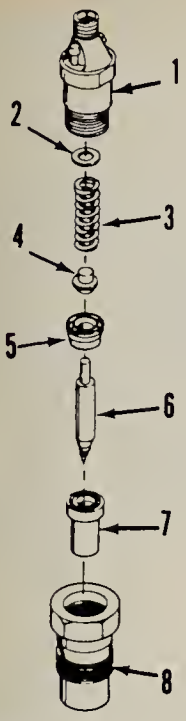


Fig. O311—Exploded view of injector nozzle used on all models.

1. Upper body
2. Shim
3. Spring
4. Spring seat
5. Stop plate
6. Nozzle needle
7. Nozzle valve body
8. Nozzle holder

operation. Exhaust valve guides are 6 mm (0.236 inch) longer than intake guides and are not interchangeable. Guides must be pressed into cylinder head until top of guide protrudes a specified distance from top surface of head. On Spec. A and B engines, guide height should be 15.6-16.4 mm (0.614-0.645 inch). On Spec. C engines with valve rotators or spring wear plates, guide height should be 22.3-23.1 mm (0.878-0.909 inch). Inside diameter of replacement guides is semifinished and must be reamed or honed after installation to provide specified valve stem-to-guide operating clearance. Valve seats must be reground after installing new guides.

All valves are equipped with valve stem seals which should be renewed whenever valves are removed from cylinder head. Lubricate valve stem and place a plastic seal protector over end of valve stem when installing new seals. Do not remove valves after new seals are installed. Do not reuse old seals.

Some engines are equipped with positive valve rotators. Since it is difficult to determine if a rotator is good or bad, manufacturer recommends renewing rotators at time of major engine overhaul or if a build-up of carbon is evident on valve face and seat.

Valve springs are interchangeable for intake and exhaust valves. Valve spring free length should be approximately 51.0 mm (2.0 inches). Spring tension should test 287-307 N (65-69 pounds) when compressed to 42.5 mm (1.67 inches). Renew spring if test load is less than 258 N (58 pounds) at 42.5 mm (1.67 inches).

INJECTOR NOZZLE

WARNING: Fuel energes from injector with sufficient force to penetrate the skin. When testing injector, keep yourself clear of nozzle spray.

REMOVE AND REINSTALL. To remove injectors, first thoroughly clean injector, lines and surrounding area. Remove high pressure lines and fuel return lines from injectors. Cap all openings to prevent entry of dirt. Unscrew injector from cylinder head using a 27 mm deep socket. Remove and discard injector nozzle seals from injector bores.

When reinstalling injector, make certain new nozzle seal is installed with concave (inward curve) side facing down (Fig. O308).

NOTE: Incorrect installation of seal will cause nozzle valve to overheat and possibly stick. Do not reuse nozzle seals.

Tighten injectors to a torque of 69 N·m (51 ft.-lbs.). Reconnect fuel lines and bleed air from system as outlined in MAINTENANCE section.

TESTING. A complete job of testing and adjusting injectors requires use of special test equipment. Only clean, approved test oil (Viscor 1487) should be used in tester tank. Nozzle should be tested for opening pressure, leakage and spray pattern.

Before conducting tests, connect nozzle to tester and operate tester lever quickly to purge air from nozzle and make sure nozzle is not stuck.

OPENING PRESSURE. Open valve to tester gage and operate tester lever slowly while observing gage reading. Opening pressure should be 13000-13800 kPa (1890-2000 psi).

Opening pressure is adjusted by changing thickness of shim (2–Fig. 0311). A change in shim thickness of 0.04 mm (0.0016 inch) will result in a pressure change of approximately 500 kPa (72 psi).

SEAT LEAKAGE. To check for leakage, operate tester lever to maintain gage pressure 1035 kPa (150 psi) below opening pressure. If a drop falls from nozzle tip within 10 seconds, nozzle valve must be cleaned or renewed.

SPRAY PATTERN. To check spray pattern, tester lever must be actuated to produce 4-6 nozzle opening cycles per second. At slower speeds, fuel will not be properly atomized. Spray pattern should be uniform and well atomized emerging in a straight axis from nozzle tip. When opening properly, nozzle will operate with a high pitched chatter.

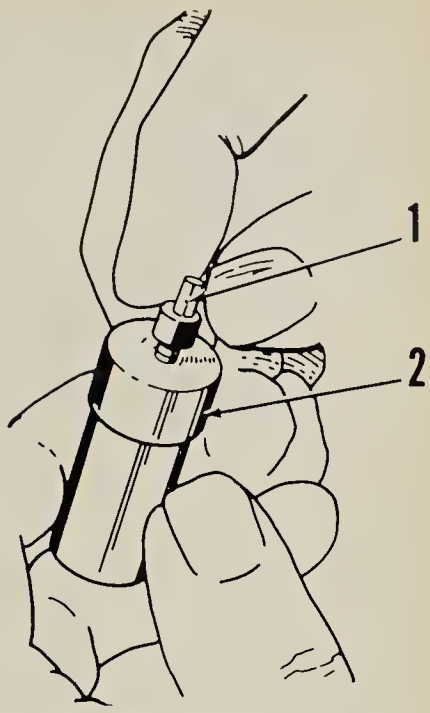


Fig. O312—Nozzle needle (1) must slide freely in nozzle body (2). Reclean or renew nozzle valve assembly if needle fails to slide down to its seat by its own weight with body held at 45° angle.

OVERHAUL. Hard or sharp tools, emery cloth, steel wire wheels or grinding compounds should never be used when servicing injectors. An approved nozzle cleaning kit is available from Onan and from a number of other specialized sources. Do not attempt to disassemble nozzle without proper test equipment to adjust opening pressure.

Clean outside of nozzle prior to disassembly. Secure nozzle body in a vise or holding fixture. Remove nozzle valve holder (8–Fig. O311) and separate components from nozzle body. Place all parts in clean calibrating oil or diesel fuel as they are removed.

NOTE: Nozzle valve components are mated parts and must be kept together. Never interchange components between nozzle assemblies.

Soak all parts in an approved carbon solvent, if necessary, to loosen hard carbon deposits. Rinse parts in clean diesel fuel or calibrating oil immediately after cleaning to neutralize the solvent and prevent etching of polished surfaces. Clean nozzle valve seat using tools from special cleaning kit. Perform the following test to nozzle valve after cleaning.

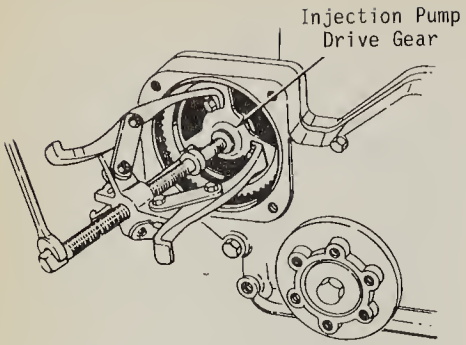


Fig. O313—Injection pump drive gear may be removed through opening in timing gear cover using a suitable gear puller.

With needle and seat thoroughly rinsed in clean diesel fuel, pull needle about one third of its length out of valve body (Fig. O312). When released, needle must slide down to bottom of seat by its own weight. If needle will not slide freely, reclean valve seat or renew nozzle valve needle and seat assembly.

When reassembling injector, do not handle polished surfaces unless hands are wet with diesel fuel. Thoroughly rinse all parts in clean diesel fuel and assemble while wet. Tighten nozzle body holder to a torque of 69 N·m (51 ft.-lbs.). Retest injector as previously outlined.

GLOW PLUGS

Glow plugs are parallel connected with each individual glow plug grounding through its mounting threads. To test glow plugs, first disconnect wires from all glow plug terminals. Using an ohmmeter, check for continuity of each glow plug. An "infininite" resistance reading indicates an open circuit and glow plug must be renewed. Glow plug tightening torque is 19 N·m (14 ft.-lbs.).

INJECTION PUMP

All models are equipped with a distributor type Roosa Master Model DB2 injection pump. The injection pump should be adjusted and repaired only by qualified injection pump service facility. Adjustments made to pump by non-qualified personnel may violate Federal, state and/or local exhaust emissions regulations and may also void manufacturer's warranty on pump and engine.

REMOVE AND REINSTALL. Before removing pump, first thoroughly clean pump and surrounding area. Shut off fuel supply. Remove timing window covers from flywheel housing and injection pump. Rotate crankshaft in normal direction until number 1 piston is on compression stroke and specified timing mark on flywheel is aligned with timing

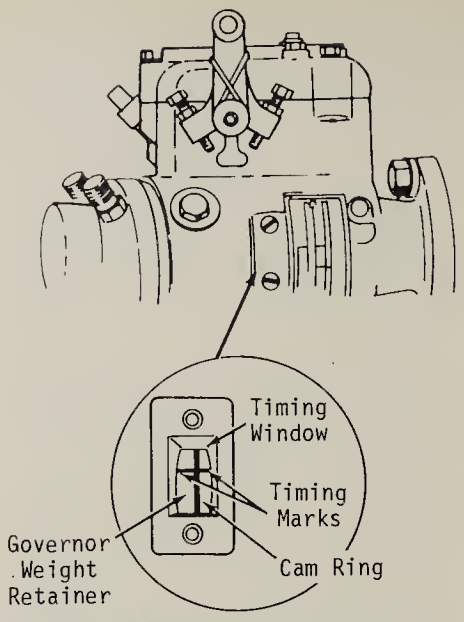


Fig. O314—Injection pump static timing is correct if pump timing marks are aligned when number 1 piston is on compression stroke and specified timing mark on flywheel is aligned with pointer.

pointer. (Specified static timing is stamped on engine model plate.) At this point, pump timing marks (Fig. O314) should be aligned as shown. Disconnect throttle cable from pump control lever. Disconnect all fuel lines from pump and plug all openings. Disconnect electrical wiring from fuel shut-off solenoid. Remove cover plate from front of timing gear housing. Remove nut securing injection pump drive gear to pump shaft. Use a suitable puller to remove drive gear from pump shaft (Fig. O313). Radiator and shroud will need to be removed on most applications to provide working clearance for gear removal. Remove pump mounting stud nuts and withdraw pump from engine.

To reinstall pump, first position pump on mounting studs and tighten stud nuts finger tight. Rotate pump shaft to align timing marks on governor weight retainer and cam ring (Fig. O314). Make sure number 1 piston is on compression stroke and specified timing mark on flywheel is aligned with timing pointer. Install pump drive gear onto pump shaft and tighten retaining nut to a torque of 52 N·m (38 ft.-lbs.). Recheck alignment of pump timing marks and rotate pump to align marks if necessary. Tighten pump stud nuts to a torque of 23 N·m (17 ft.-lbs.). Complete installation by reversing the removal procedure. Bleed air from system as outlined in MAINTENANCE section.

FUEL TRANSFER PUMP

A diaphragm type fuel transfer pump, mounted on right side of engine is used

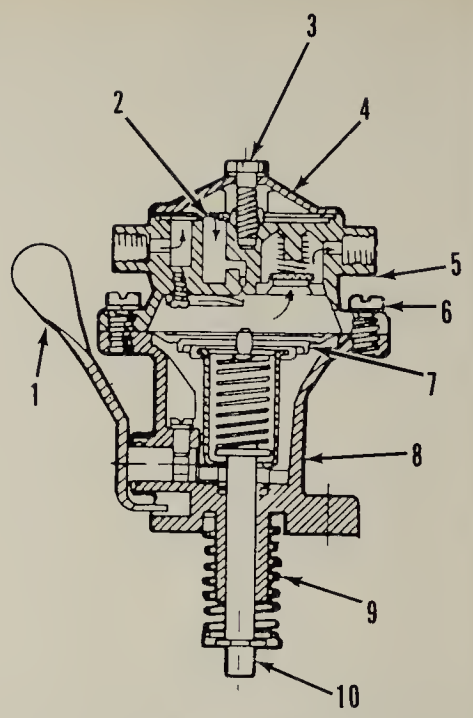


Fig. O315—Exploded view of fuel transfer pump used on all models.

1. Manual priming lever
2. Filter
3. Cap screw
4. Cap
5. Pump cover
6. Screw
7. Diaphragm
8. Pump body
9. Push rod spring
10. Push rod

to maintain positive fuel pressure to inlet of fuel injection pump. Transfer pump is driven by a cam lobe on engine camshaft. Transfer pump operating pressure should be 26-48 kPa (4-7 psi) at engine idle speed.

To remove pump, shut off fuel and disconnect fuel lines. Unbolt and remove pump from engine.

Prior to disassembly, scribe mating marks on pump cover and body to aid alignment during reassembly. Remove cap (4 – Fig. O315) and filter (2). Remove six screws retaining cover (5), then carefully remove cover. Compress push rod spring (9) and remove spring retaining ring. Withdraw spring, push rod (10) and diaphragm (7).

Clean and inspect all parts for wear or damage. A kit is available for renewal of gaskets, diaphragm and filter.

To reassemble, install diaphragm, push rod and spring. Compress spring and install retaining ring. Assemble cover to body aligning mating marks. Tighten retaining screws to a torque of 2-3 N·m (17-26 in.-lbs.). Position filter with spacer legs facing upward, then install cap and tighten cap screw to a torque of 2-3 N·m (17-26 in.-lbs.).

Reinstall pump and bleed air from system as outlined in MAINTENANCE section.

WATER PUMP

A centrifugal type water pump is used to circulate coolant through the cooling

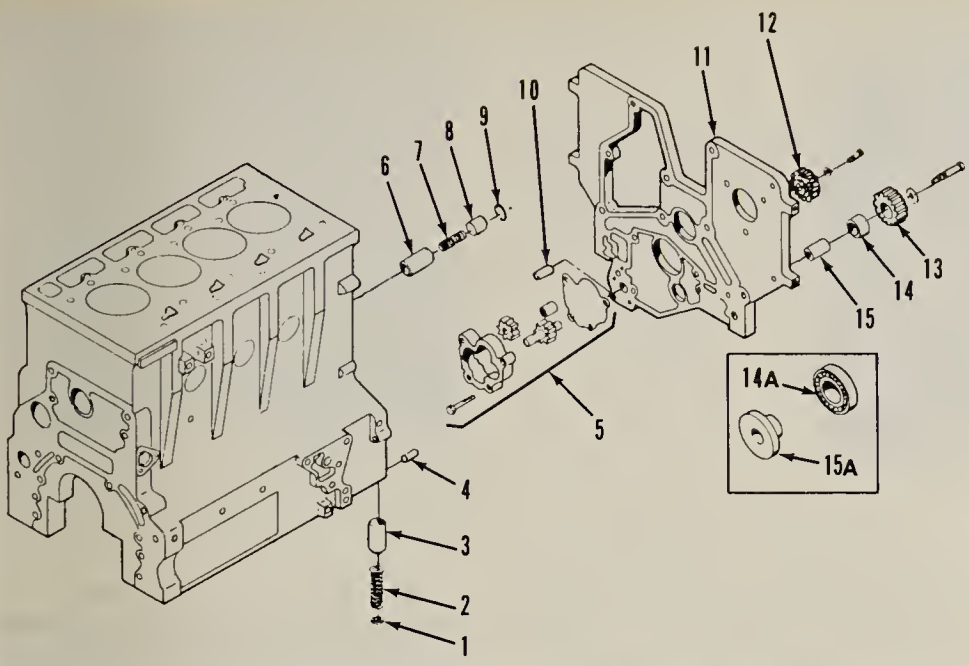


Fig. O316—Exploded view of engine oil pump and pump drive gears. Pressure relief valve (6 through 10) is used only on engines equipped with an oil cooler. Idler gear retainer (15A) and bearing (14A) are used on engines equipped with front pto.

1. Washer
2. Spring
3. Pressure regulator piston
4. Valve retaining pin
5. Oil pump assy.
6. Relief valve body
7. Spring
8. Relief valve piston
9. Snap ring
10. Bushing
11. Timing gear back plate
12. Pump drive gear
13. Idler gear
14. Bushing
15. Idler shaft

system. Two sizes of pumps along with two different impellers for each pump and a variety of different drive pulleys are used depending upon engine application and cooling requirements.

Service parts are not available for water pump repair. If seal is leaking or bearing feels rough or binds, water pump must be renewed as a unit.

OIL PUMP

The gear type oil pump is mounted to rear of timing gear housing back plate and is driven by the crankshaft through an idler gear. An oil pressure regulating valve, located in main oil gallery at front of cylinder block, maintains oil pressure at 345-380 kPa (50-55 psi) at high idle speed. On engines equipped with an oil cooler, a safety relief valve is also used to limit pump discharge pressure. Safety relief valve opens at 830 kPa (120 psi). Relief valve is located in front of cylinder block just above the oil pump.

Oil pump is accessible after removing engine oil pan. Note location of shorter cap screw when removing oil pickup from oil pump body. Remove oil pump drive gear (12 – Fig. O316), then separate pump gears from body.

Inspect all parts for excessive wear or other damage. Radial clearance between pump gears and body bore should not exceed 0.175 mm (0..07 inch). Maximimum allowable end clearance of gears to body is 0.150 mm (0.006 inch). Maximum allowable drive shaft clearance in body is 0.07 mm (0.003 inch). Drive shaft clearance in bushing must not exceed 0.15 mm (0.006 inch). Idler shaft clearance in gear must not exceed 0.06 mm (0.002 inch). Renew pump assembly if wear limits are exceeded.

To reinstall pump, reverse the removal procedure. Tighten oil pump and pick up tube mounting cap screws evenly in two steps to a final torque of 23 N·m (17 ft.-lbs.). Be sure oil pump gears rotate freely after tightening mounting screws. Tighten oil pump drive gear and idler gear cap screws to a torque of 23 N·m (17 ft.-lbs.). Tighten oil pan mounting screws, starting at the center and working outward to each end, to a torque of 11 N·m (8 ft.-lbs.).

OIL COOLER

Some engines are equipped with an oil cooler mounted on left side of engine block. If a drop in oil pressure occurs due to oil overheating, the oil cooler could be restricted. Oil cooler should be cleaned or renewed. If lubrication system is contaminated with metal particles from an engine failure, oil cooler should be renewed. Do not attempt to clean metal particles from oil cooler.

Oil cooler may be pressure tested for leaks using air pressure not to exceed 138 kPa (20 psi). Renew cooler core if faulty.

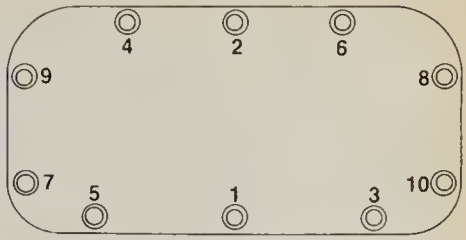


Fig. O317—Tighten oil cooler (models so equipped) mounting cap screws evenly using torque sequence shown. Retorque cap screws after two hours of operation.

When reinstalling oil cooler, tighten mounting cap screws gradually and evenly using tightening sequence shown in Fig. O317. Tighten to a final torque of 22 N·m (16 ft.-lbs.). Retorque cooler cap screws after two hours of operation.

TIMING GEARS AND COVER

To remove timing gear cover, first drain coolant and remove radiator. Remove fan belt, fan, alternator and mounting bracket and crankshaft pulley. Loosen oil pan mounting cap screws and lower front end of oil pan. Remove timing gear cover cap screws, tap cover to loosen gasket seal and withdraw cover from engine. Crankshaft front oil seal is located in timing gear cover and may be renewed at this time.

Inspect timing gears for excessive wear, chipped teeth or other damage. Maximum allowable backlash between any two gears is 0.30 mm (0.012 inch). Idler gear end play should not exceed 0.40 mm (0.016 inch). Idler gear bushing and stub shaft are renewable. Bushing inside diameter should be 40.030-40.054 mm (1.576-1.577 inches) and stub shaft outer diameter should be 39.986-40.000 mm (1.5742-1.5748 inches). Maximum allowable bushing bore to shaft clearance is 0.10 mm (0.004 inch). Idler gear bushing is furnished semifinished and bushing bore must be reamed to correct size after pressing into gear. Camshaft gear and crankshaft gear are press fitted to their respective shafts. Refer to appropriate sections for shaft removal and installation if gears require renewal.

When reassembling timing gears, make certain timing marks (Fig. O318) on idler gear are aligned with corresponding marks on crankshaft gear and camshaft gear. There are no timing marks on injection pump drive gear. Refer to INJECTION PUMP section for gear removal and installation and pump timing procedure.

Renew crankshaft front oil seal and wear sleeve as outlined in CRANKSHAFT OIL SEAL paragraph. Lubricate lip of oil seal with oil or grease before reinstalling cover. Tighten cover mounting cap screws to a torque of 23

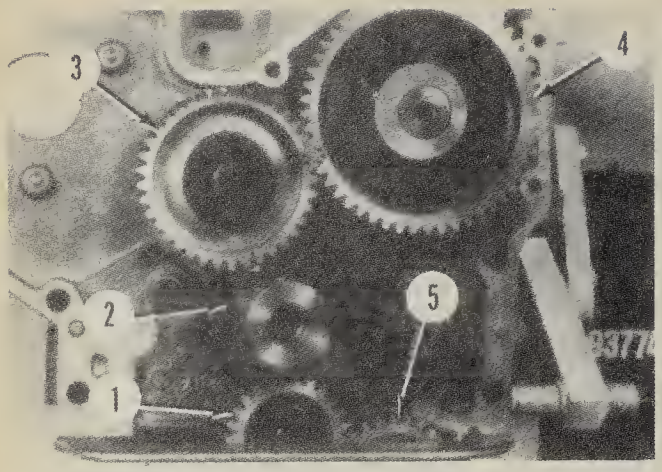


Fig. O318—Valve timing is correct when single dot on idler gear (3) is aligned with single dot on crankshaft gear (2) and two dots on idler gear are aligned with two dots on camshaft gear (4).
1. Oil pump idler gear
2. Crankshaft gear
3. Idler gear
4. Camshaft gear
5. Oil pump drive gear

N·m (17 ft.-lbs.). Tighten oil pan cap screws to a torque of 11 N·m (8 ft.-lbs.). Complete installation by reversing the removal procedure.

CAMSHAFT AND BEARINGS

REMOVE AND REINSTALL. To remove camshaft, first remove timing gear cover and cylinder head as previously outlined.

NOTE: Camshaft may be removed without removing cylinder head by first removing push rods, then use a pencil magnet to lift cam followers out of their bores in cylinder block.

With cylinder head removed, withdraw cam followers keeping all parts separated in order of removal so they can be reinstalled in their original locations. Remove fuel transfer pump. Rotate camshaft to remove retaining plate cap screws through openings in camshaft gear. Withdraw camshaft assembly from cylinder block being careful not to damage camshaft bushings. Remove idler gear from stub shaft for timing purposes.

Using a feeler gage, check end clearance between retainer plate and camshaft gear. Desired end play is 0.10-0.50 mm (0.004-0.020 inch). If end play exceeds 0.70 mm (0.027 inch), renew retainer plate and/or gear. Camshaft gear is keyed and press fitted to camshaft. Use a press to remove and install gear. Press gear onto shaft until it bottoms against shaft shoulder. Check cam lobes for scoring, excessive wear or other damage. Renew camshaft if height from base to tip of intake or exhaust cam lobes is less than 42.50 mm (1.673 inches). If camshaft is renewed, it is recommended that cam followers be renewed also. Camshaft bearing journal outside diameter should be 50.000-50.014 mm (1.9685-1.9691 inches). Recommended operating clearance in camshaft bushings is 0.030-0.116 mm (0.0011-0.0046 inch) and maximum allowable clearance is 0.15 mm (0.006 inch). Maximum allowable journal runout, measured at center bearing journal, is 0.10 mm (0.004 inch).

To remove camshaft bushings, the crankshaft, timing gear housing back plate and flywheel housing must first be removed. Use a suitable cam bushing puller to remove bushings. All bushings except the rear one should be pulled rearward from cylinder block bores. Pull rear bushing forward from its bore. When installing new bushings, reverse the removal procedure starting at front bushing and pulling all bushings except rear one rearward into their bores. Pull rear bushing in from the rear towards the front.

NOTE: Front bushing is wider and has two oil holes in it. Be sure both holes are aligned with corresponding oil passages in cylinder. Make certain single oil hole in each of the other bushings is aligned with oil passage from main bearing.

Cam bushings should be checked for nicks or burrs after installation. Bushings are precision type and do not require reaming or honing. Apply sealing compound to rear expansion plug before installing.

When reinstalling camshaft, thoroughly lubricate cam bushings and camshaft. Tighten retaining plate cap screws to a torque of 23 N·m (17 ft.-lbs.). Align timing marks as shown in Fig. O318 and install idler gear. Tighten idler gear cap screw to a torque of 52 N·m (39 ft.-lbs.). Complete installation by reversing removal procedure.

PISTON AND ROD UNITS

Piston and connecting rod are removed from the top after removing oil pan, oil pickup tube and cylinder head. Remove carbon ridge and ring ridge (if present) from top of cylinder before attempting to remove piston. A piece of rubber tubing may be placed over ends of connecting rod bolts during removal and installation to avoid scratching cylinder wall or crankpin journal.

NOTE: Mark and number each piston and connecting rod assembly so it can be returned to its respective cylinder. The connecting rod and cap are marked with identifying numbers and must be kept together.

When reinstalling piston and rod assembly, thoroughly lubricate piston and cylinder with clean engine oil. Piston and rod units should be reinstalled in their original locations. Make certain connecting rod identification marks (1—Fig. 0319) are facing camshaft side of engine and piston swirl chamber is towards intake side of engine. Tighten rod cap nuts evenly in steps to a final torque of 85 N·m (63 ft.-lbs.).

PISTON, PIN AND RINGS

All models are equipped with two compression rings and one oil control ring. Piston and rings are available in oversizes as well as standard size. Piston to cylinder clearance, measured at right angle to piston pin bore, should be 0.127-0.173 mm (0.0050-0.0068 inch). If clearance exceeds 0.250 mm (0.010 inch), cylinders should be bored oversize and pistons and rings renewed.

Full floating piston pins are retained in piston by snap rings at each end. Standard piston pin diameter is 31.995-32.00 mm (1.2596-1.2598 inches). Pin bore in piston should be 32.003-32.009 mm (1.2599-1.2601 inches). Rec-

Fig. O319—Swirl chamber (2) of piston should be positioned opposite connecting rod identification number (1).

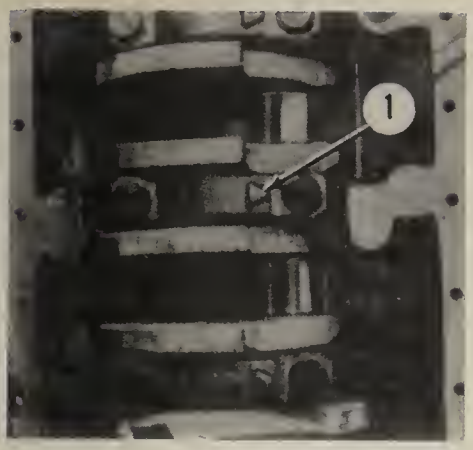


Fig. O320—Raised arrow (1) on main bearing caps should point towards camshaft side of engine.

ommended operating clearance of pin in piston is 0.003-0.014 mm (0.0001-0.0005 inch) and maximum allowable clearance is 0.03 mm (0.0012 inch).

Piston ring groove wear may be checked between ring and top of ring groove with a feeler gage. Renew piston if side clearance exceeds 0.25 mm (0.010 inch) for top and second compression ring groove. Maximum allowable clearance for oil control ring groove is 0.15 mm (0.006 inch).

Piston ring end gap is checked by inserting ring squarely into cylinder bore and measuring end gap with a feeler gage. Recommended end gap for both compression rings is 0.31-0.57 mm (0.012-0.022 inch). End gap for oil ring should be 0.22-0.58 mm (0.009-0.023 inch). Maximum allowable end gap for all rings is 1.50 mm (0.060 inch). Filing ring ends to increase end gap is not recommended.

When reinstalling rings, assemble oil ring end gap 180° from guide pin in ring expander. Install compression rings in correct grooves with sides marked "Up 2nd" and "Up Top" or with a dot towards top of piston. Be sure ring end gaps are staggered evenly around piston.

Heating piston in hot water prior to assembly will make piston pin installation easier. Be sure pin retaining rings are installed with sharp edge facing outward. Piston must be assembled with swirl chamber (2—Fig. 0319) positioned opposite identification number (1) side of connecting rod.

CONNECTING ROD AND BEARINGS

Connecting rods are equipped with a renewable bushing in the small end and precision, insert type bearings in the large end.

Recommended operating clearance between crankpin and bearing is 0.030-0.091 mm (0.0012-0.0036 inch) and maximum allowable clearance is 0.15 mm (0.006 inch). Connecting rod side clearance should be 0.05-0.045 mm (0.002-0.018 inch). Renew connecting rod if side clearance exceeds 0.45 mm (0.018 inch).

When renewing piston pin bushing, be sure oil hole in bushing is aligned with oil passage in top end of connecting rod. Bushings must be reamed or honed to correct size after being pressed into rod. Recommended inside diameter of bushing is 32.01-32.02 mm (1.2602-1.2606 inches). Desired clearance between piston pin and bushing is 0.010-0.025 mm (0.0004-0.0010 inch) and maximum allowable clearance is 0.05 mm (0.002 inch). A new piston pin installed in a new bushing at 21°C (70°F) should be a thumb push fit.

CRANKSHAFT AND BEARINGS

To remove crankshaft, first remove oil pan, cylinder head, pistons and rods, timing gear cover, idler gear, camshaft, injection pump, timing gear back plate, flywheel and flywheel housing. Unbolt and remove main bearing caps, then carefully lift out crankshaft.

Inspect crankshaft journals for scoring, excessive wear or signs of overheating. Out-of-round or taper of journals should not exceed 0.005 mm (0.0002 inch). Crankshaft may be reground undersize. Bearings are available in 0.25, 0.50 and 0.75 mm undersizes.

Main bearing journal standard diameter is 75.99-76.01 mm (2.9917-2.9925 inches). Main bearing operating clearance should be 0.03-0.10 mm (0.0012-0.0039 inch) and maximum allowable clearance is 0.15 mm (0.006 inch).

Crankpin journal standard diameter is 55.99-56.01 mm (2.2043-2.2051 inches). Connecting rod bearing operating clearance should be 0.03-0.09 mm (0.0012-0.0036 inch) and maximum allowable clearance is 0.15 mm (0.006 inch).

Crankshaft end play is controlled by thrust flanges on rear main bearing. Recommended end play is 0.10-0.33 mm (0.004-0.013 inch) and maximum allowable end play is 0.38 mm (0.015 inch).

Inspect crankshaft gear for chipped teeth or excessive wear. Use a suitable gear puller to remove gear. When installing new gear, first heat gear to about 175°C (350°F). Align gear with key in crankshaft and make sure timing mark on gear faces forward. Drive or press gear onto crankshaft until it bottoms against shaft shoulder.

To reinstall crankshaft, proceed as follows: Note that main bearing insert halves are marked UPPER or LOWER and also marked for position in cylinder block. Assemble upper bearing halves in their designated positions in block. Be sure bearing tangs engage slots in block. Lubricate with clean engine oil, then carefully lower crankshaft into block. Assemble lower bearing halves in their respective caps. (Bearing caps are marked in numerical order and also front and rear caps are marked "F" and "R" respectively. Be sure bearing tangs engage slots in bearing caps. Install bearing caps. Install bearing caps in proper locations with raised arrow (1—Fig. O320) on caps pointing towards camshaft side of engine. Push crankshaft towards front of engine to align rear bearing thrust surfaces, then tighten bearing cap mounting cap screws alternately and in steps to a final torque of 123 N·m (90 ft.-lbs.). Be sure crankshaft turns freely after cap screws are torqued. Complete installation by reversing the removal procedure.

CRANKSHAFT OIL SEALS

FRONT SEAL. The front oil seal is located in timing gear cover. A wear sleeve is available with replacement seal to service a damaged or grooved crankshaft.

To renew seal, timing gear cover must be removed as previously outlined. Be sure new seal is pressed squarely into cover bore and is bottomed against cover shoulder. Outer diameter of a new seal is coated with a sealant which eliminates the need for using a sealing compound when installing seal. Be sure open side of seal faces inward and seal lip is lubricated with oil or grease prior to assembly.

To remove a previously installed wear sleeve from crankshaft, use a chisel to make two marks across wear sleeve about three-quarters of the way through sleeve. This will expand sleeve to allow easier removal. Be careful not to damage crankshaft surface.

Apply Loctite 271 to crankshaft and inside of new wear sleeve, then install sleeve onto crankshaft making certain outside chamber of sleeve faces forward. A special installing tool, Number 420-0418, is available from Onan to properly position and install wear sleeve. Clean excess Loctite from crankshaft and wear sleeve.

REAR SEAL. Crankshaft rear oil seal is located in seal retainer plate which is bolted to rear of block. A wear sleeve is pressed onto crankshaft flange to protect crankshaft from wear and to provide a smooth sealing surface for oil seal.

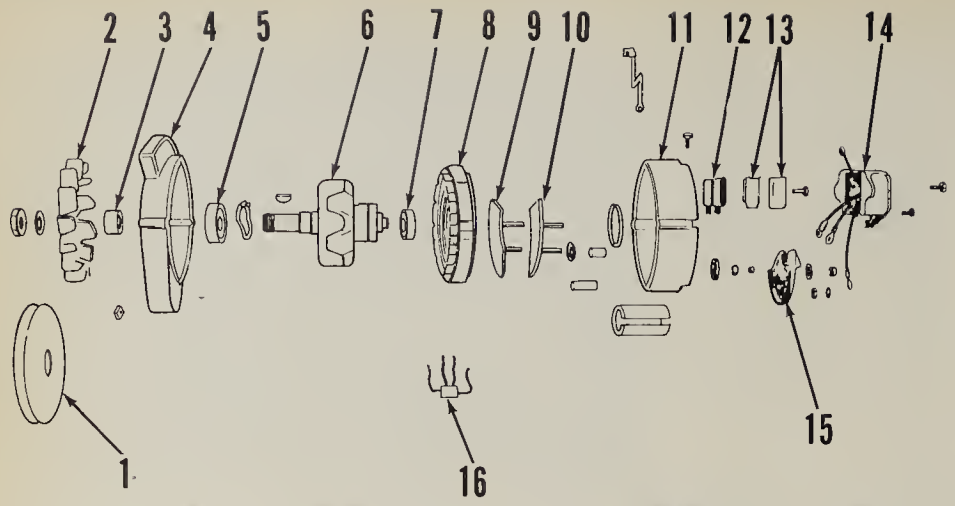


Fig. O321—Exploded view of alternator assembly. Isolation diode assembly (15) was used on early models and diode trio (16) is used on late models.

1. Pulley
2. Fan
3. Spacer
4. Front cover
5. Bearing
6. Rotor
7. Bearing
8. Stator
9. Negative diode rectifier
10. Positive diode rectifier
11. End frame
12. Brush assy.
13. Cover plates
14. Voltage regulator
15. Isolation diode assy.
16. Diode trio

To renew seal, first remove flywheel and flywheel housing. Remove seal retainer plate and drive out old seal. Press a new seal into retainer plate using a suitable seal installing tool until outer surface of seal is flush with machined surface of retainer plate. A special oil seal and wear sleeve installing tool (number 420-0417) is available from Onan. Be sure open side of seal faces inward. Lubricate seal lip with oil or grease prior to assembly onto crankshaft.

To renew wear sleeve, use a hammer and chisel to make chisel marks across wear sleeve about three-quarters of the way through. This will expand sleeve to allow removal from crankshaft. Be careful not to damage crankshaft flange.

NOTE: if wear sleeve special installing tool is not available, note position of wear sleeve on crankshaft flange so new sleeve can be installed in same position.

Apply Loctite 271 to crankshaft flange and inside of new sleeve. Position sleeve on crankshaft so outer chamfer side is facing rearward. Press sleeve onto crankshaft flange with special installing tool until tool bottoms against end of crankshaft. Wipe excess Loctite from crankshaft and sleeve.

Reinstall seal retainer plate making sure seal is centered on crankshaft flange. Tighten retainer plate mounting cap screws to a torque of 23 N·m (17 ft.-lbs.) and oil pan cap screws to 11 N·m (8 ft.-lbs.). Tighten flywheel housing cap screws to a torque of 84 N·m (62 ft.-lbs.) and flywheel mounting cap screws to 68 N·m (50 ft.-lbs.).

FLYWHEEL AND RING GEAR

The flywheel is indexed to crankshaft with a dowel pin and retained by six cap screws. Flywheel can be installed in one position only.

If engine is equipped with a clutch, inspect flywheel friction surface for grooves, cracks or other damage. A maximum of 0.40 mm (0.016 inch) of material may be removed to provide a smooth surface before renewal is required. Inspect clutch shaft pilot bearing in flywheel bore and renew if worn or damaged. Press against bearing outer race only when installing new bearing.

Check ring gear for worn or broken teeth and renew if necessary. To remove ring gear, use a grinder to split ring gear at the base of one of the teeth. Then, drive ring gear off the flywheel. Heat new ring gear to 185°-195°C (365°-385°F) prior to installing onto flywheel.

NOTE: Do not overheat ring gear as gear may warp or heat treatment may be destroyed.

Drive new gear down squarely against shoulder of flywheel. Gear must be driven on quickly before it cools and contracts to flywheel in the wrong position.

To reinstall flywheel, reverse the removal procedure. Tighten mounting cap screws using a star pattern sequence in two steps to a final torque of 68 N·m (50 ft.-lbs.).

ELECTRICAL SYSTEM

ALTERNATOR AND REGULATOR. Refer to Fig. O321 for an exploded view of alternator assembly. Normal alternator output voltage should be between 13.8-14.8 volts with engine operating at approximately 1000 rpm. If output voltage is too low, connect a jumper wire from positive output post to field post and recheck output voltage. If

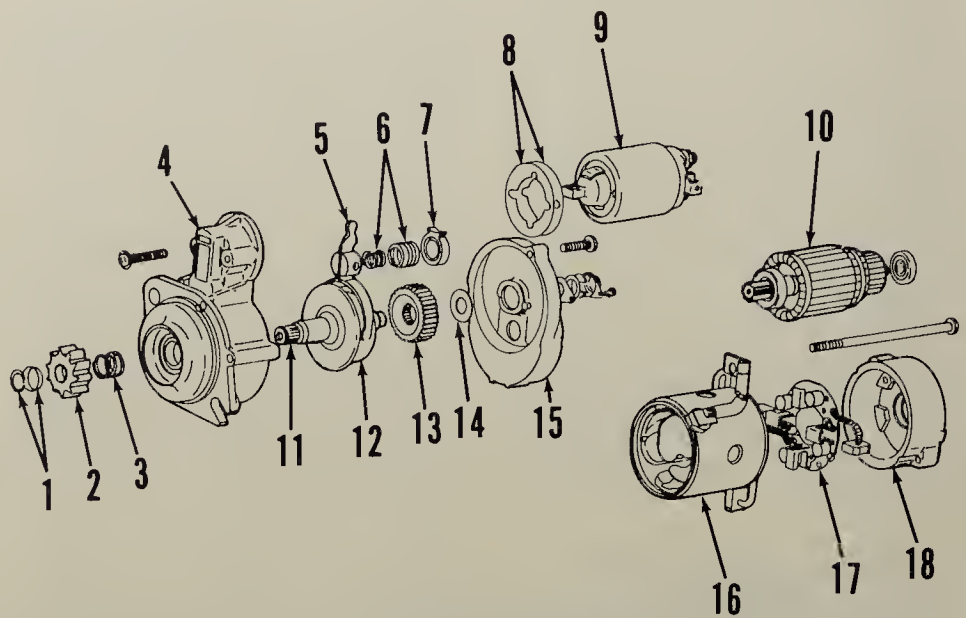


Fig. O322—Exploded view of Mitsubishi starter motor. A Delco-Remy starter motor (not shown) is used on some models.

1. Pinion stop ring
2. Pinion gear
3. Spring
4. Front housing
5. Lever
6. Springs
7. Seal
8. Fiber washers
9. Solenoid
10. Armature
11. Pinion shaft
12. Overrunning clutch
13. Reduction gear
14. Washer
15. Center housing
16. Frame & field coil assy.
17. Brush holder & brushes
18. End cover

voltage is unchanged, alternator is defective. If voltage is now within specifications or higher, regulator is defective. The solid state regulator is not adjustable.

Voltage regulator and brushes may be renewed without disassembling alternator. Renew brushes if less than 4.2 mm (0.165 inch) of brush extends below bottom of holder.

Before disassembling alternator, place scribe mark across end frame and front cover to provide proper alignment when reassembling. Check stator and rotor windings for open or grounded circuits. Diodes should have continuity in one direction only. Renew faulty components or alternator assembly as required.

STARTER. Refer to Fig. O322 for an exploded view of electric starter motor. When disassembling starter, be sure to retain all shims and washers for use in reassembly.

Check armature for continuity between commutator segments. No continuity indicates an open circuit and armature must be renewed. Test for continuity between armature shaft and each commutator segment. Continuity indicates a grounded circuit and armature must be renewed. Use a growler to check armature for short circuits.

To check field coil, test for continuity between brushes. No continuity indicates a defective field coil. There should be no continuity between field coil and starter frame.

Minimum brush length is 11.5 mm (0.435 inch). Check for continuity between positive side of brush holder and brush holder base. Continuity indicates a short circuit and holder assembly should be renewed.

Inspect reduction gears and overrunning clutch for wear and damage. Pinion gear should be free to turn in one direction and lock when turned in opposite direction.

NOTE: Do not clean overrunning clutch in solvent. Washing clutch will cause grease to leak out.

When reassembling, apply light coat of grease to all gears, armature bearings sleeve bearing and sliding portion of lever assembly. Install adjusting washers (14 – Fig. O322) between center housing (15) and reduction gear (13) to obtain recommended pinion shaft end play of 0.1-0.8 mm (0.004-0.031 inch). To adjust pinion gap, disconnect positive terminal "M" on solenoid. Connect positive terminal of battery to "S" terminal on solenoid and negative terminal to starter body. This will shift pinion gear forward into cranking position. Then, lightly push pinion rearward and measure the gap. Desired pinion gap is 0.3-2.0 mm (0.012-0.079 inch). If necessary, change number of fiber washers (8) used between solenoid and front housing. Adding washers will decrease pinion gap.

PERKINS

PERKINS ENGINES, INC.
32500 Van Born Road
Wayne, Michigan 48184

Model	No. Cyls.	Bore	Stroke	Displ.
3.152	3	91.44 mm (3.6 in.)	127 mm (5.0 in.)	2502 cc (152 cu. in.)
D3.152, AD3.152	3	91.44 mm (3.6 in.)	127 mm (5.0 in.)	2502 cc (152 cu. in.)
3.1522	3	91.44 mm (3.6 in.)	127 mm (5.0 in.)	2502 cc (152 cu. in.)
3.1524, T3.1542	3	91.44 mm (3.6 in.)	127 mm (5.0 in.)	2502 cc (152 cu. in.)

All engines in this section are liquid-cooled, four-stroke diesels with vertical, inline cylinders. The 3.152 engine uses indirect type fuel injection while all other engines are direct injection diesels. "Front" of engine refers to crankshaft pulley end of engine. Firing order is 1-2-3 with number 1 cylinder at "front" of engine. Crankshaft rotation is clockwise viewed from the "front". Model T3.1524 is equipped with a turbocharger. The engine identification number is stamped on the right side of engine cylinder block, forward of the fuel lift pump on all engines.

MAINTENANCE

LUBRICATION

Recommended crankcase oil is SAE 10W for temperatures between minus 18°C (0°F) to minus 1°C (30°F), SAE 20W for temperatures between minus 1°C (30°F) and 27°C (80°F) and SAE 30 for temperatures above 27°C (80°F). Use of multigrade oils is acceptable. Oils for naturally aspirated engines should meet MIL-L-46152 or MIL-L-2104C specifications. However, if engine is new or just overhauled, manufacturer does not recommend using MIL-L-2104C specification oil in naturally aspirated engines until after the first oil change. Lubricating oil for turbocharged engines must meet MIL-L-2104C specification.

Engine oil and filter element should be renewed after every 250 hours of operation. Crankcase capacity is approximately 7.4 liters (7.8 quarts) for 3.152 and D3.152 engines and 6.8 liters (7.2 quarts) for all other engines. Capacity can vary depending on engine application; fill to "FULL" mark on dipstick.

Oil pressure relief valve setting is 345-448 kPa (50-65 psi).

COOLING SYSTEM

Manufacturer recommends using a mixture of water and ethylene glycol antifreeze in cooling system. In addition to providing protection against freezing, the antifreeze solution contains additives to protect against corrosion and also raises the boiling point of the coolant. If an antifreeze solution is not used, an approved corrosion inhibitor should be added to the water.

FUEL SYSTEM

FUEL FILTER AND BLEEDING. All engines are equipped with a renewable, paper element type fuel filter. Some engines are equipped with two filter elements, an intermediate element and a final filter element. A water trap and sediment bowl may also be used between the fuel tank and fuel lift pump. The water trap should be cleaned after every 250 hours of operation or more often if water or sediment is evident in the bowl. The fuel filter elements should be renewed after every 500 hours of operation or once a year, whichever comes first. However, if engine indicates signs of fuel starvation (surging or loss of power), filters should be renewed regardless of hours of operation.

Whenever fuel filters are renewed or fuel lines have been disconnected, air must be bled from the fuel system as follows: Loosen vent screw (1–Fig. PR1) on side of injection pump governor cover and screw (2) on side of fuel pump body. Manually actuate primer lever on fuel lift pump until air-free fuel flows from vent screws. Retighten pump body screw first, then governor cover screw. If engine fails to start at this point, loosen high pressure fuel line fittings at the injectors. Place pump control in "run" position and throttle in full speed position, then crank engine until fuel is discharged from loosened fuel line fittings. Retighten fittings and start engine.

ENGINE SPEED ADJUSTMENT. The engine maximum no-load speed setting can be established from the identification plate. A typical code is XW50E600/8-2470. The last four numbers indicate the specified no-load speed which is 2470 rpm in this case. If a replacement pump is being installed, be sure to stamp the setting code number from the old pump on the identification plate of the new pump.

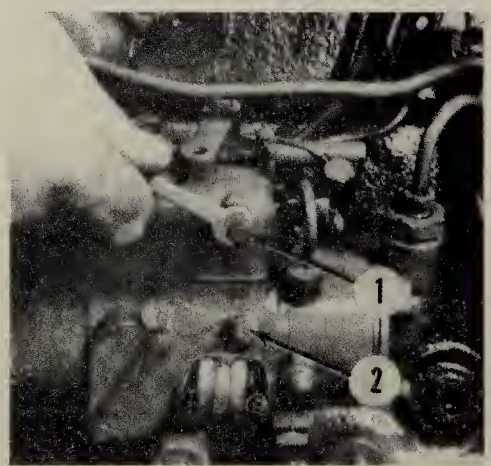


Fig. PR1-1—Loosen vent screws (1 and 2) on side of injection pump to bleed air from fuel system.

Fig. PR1-2—The "E" scribe line on injection pump rotor should align with square end of snap ring when number 1 piston is at specified static timing position. Refer to text.

The engine must be at normal operating temperature and an accurate tachometer used when adjusting engine speed setting. Adjust throttle lever stop screw until correct speed is obtained. After completing adjustment, install a seal wire on adjusting screw to secure adjustment.

INJECTION PUMP TIMING. The injection pump drive shaft has a milled slot in forward end which engages a dowel pin in pump drive gear. Thus, injection pump can be removed and reinstalled without regard to timing position.

To check the pump timing, shut off fuel and remove timing window cover from side of pump housing. A snap ring is provided inside pump for timing purposes (Fig. PR1-2). When scribed line "E" on pump rotor is aligned with square end of snap ring, beginning of injection to number 1 cylinder should occur. If correct setting of snap ring is in doubt, pump must be removed to adjust snap ring position. Connect an injector test pump to number 1 outlet fitting, then actuate test pump to obtain pressure of 9750 kPa (440 psi). Rotate injection pump shaft by hand until it locks up. Adjust snap ring position so square end is aligned with line marked "E" on pump rotor. Reinstall pump.

Remove valve cover and rotate crankshaft until number 1 piston is at TDC on compression stroke (exhaust valve on number 3 cylinder will be fully open.) Remove valve spring from number 1 intake valve and allow valve to rest on piston crown.

NOTE: Install a piece of wire or rubber band around valve stem to prevent valve from accidentally falling into cylinder.

Mount a dial indicator on end of the intake valve stem, then turn crankshaft and zero indicator at top dead center. Turn crankshaft in opposite direction of rotation approximately ⅛ turn. Then turn crankshaft in normal direction until piston is at specified BTDC position as listed in the following timing table. The correct timing figures can be found by reference to prefix letters and numbers of the setting code on the injection pump name plate.

Prefix Code	Static Timing (BTDC)	Piston Position (BTDC)
3.152 Engine:		
LW45, LW49	16°	3.15 mm (0.124 in.)
LW51, LW52	18°	3.94 mm (0.155 in.)
LW58, LW59	22°	5.84 mm (0.230 in.)
PW43, PW44	16°	3.15 mm (0.124 in.)
PW50	16°	3.94 mm (0.155 in.)
D3.152 Engine:		
MW47E, MW49, MW53E, MW57	24°	6.86 mm (0.270 in.)
RW50, RW52, RW54, SW46	24°	6.86 mm (0.270 in.)
SW46*, SW46L	29½°	10.43 mm (0.411 in.)
SW48*	26°	8.00 mm (0.315 in.)
SW52*, SW57, SW58	24°	6.86 mm (0.270 in.)
TW48E	20°	4.88 mm (0.192 in.)
TW50	22°	5.84 mm (0.230 in.)
WW, WW74E, WW48	16°	3.15 mm (0.124 in.)
WW49L	20°	4.88 mm (0.192 in.)
3.1522 Engine:		
XW50E	14°	2.37 mm (0.092 in.)
3.1524 Engine:		
WW47E, WW49L	20°	4.87 mm (0.192 in.)
ZW	24°	6.98 mm (0.275 in.)
T3.1524 Engine:		
YW	16°	3.15 mm (0.124 in.)

*Used in Lincoln electric welding sets.

With piston at specified BTDC position, scribed line "E" on pump rotor should be in line with square end of snap ring. If timing mark is not aligned, loosen pump mounting nuts and move pump in slotted mounting holes until mark is aligned. If timing mark cannot be aligned by shifting pump on mounting studs, timing gear cover should be removed and gear timing checked.

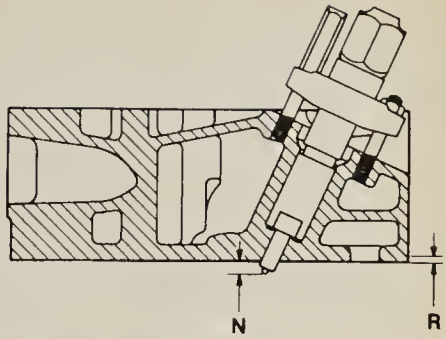


Fig. PR1-3—When remachining cylinder head surface on all engines except 3.152, a maximum of 0.30 mm (0.012 inch) of material (R) may be removed. Nozzle tip protrusion (N) must not exceed 4.67 mm (0.184 inch) on D3.152 engine or 6.32 mm (0.249 inch) on 3.1522, 3.1524 and T3.1524 engines.

REPAIRS

TIGHTENING TORQUES

Refer to the following table for special tightening torques.

Balance weight . . . . . 75 N·m (55 ft.-lbs.)
Camshaft gear . . . . . 28 N·m (21 ft.-lbs.)
Connecting rod nuts:
  Nonplated, self-locking . . . . . 95 N·m (70 ft.-lbs.)
  Cadmium plated . . . . . 61 N·m (45 ft.-lbs.)
  Phosphated . . . . . 81 N·m (60 ft.-lbs.)
Crankshaft pulley:
  With 4.8 mm (0.189 in.) thick washer . . . . . 142 N·m (105 ft.-lbs.)
  With 8.9 mm (0.350 in.) thick washer . . . . . 325 N·m (240 ft.-lbs.)
Cylinder head . . . . . Refer to text.
Flywheel . . . . . 106 N·m (78 ft.-lbs.)
Idler gear . . . . . 68 N·m (50 ft.-lbs.)
Injector . . . . . 16 N·m (12 ft.-lbs.)
Main bearing caps . . . . . 150 N·m (110 ft.-lbs.)

VALVE ADJUSTMENT

Valve clearance is adjusted with engine cold. On 3.152 and D3.152

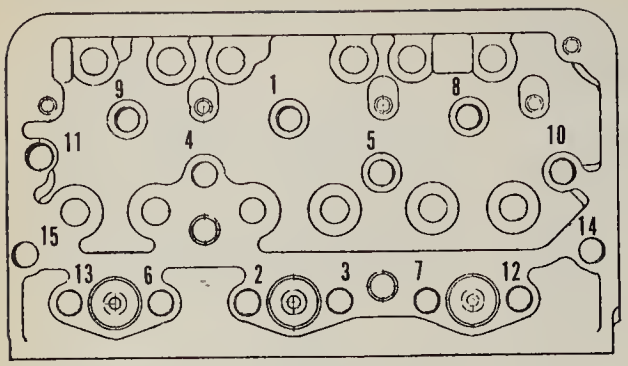


Fig. PR1-4—Cylinder head tightening sequence for 3.152 engine.

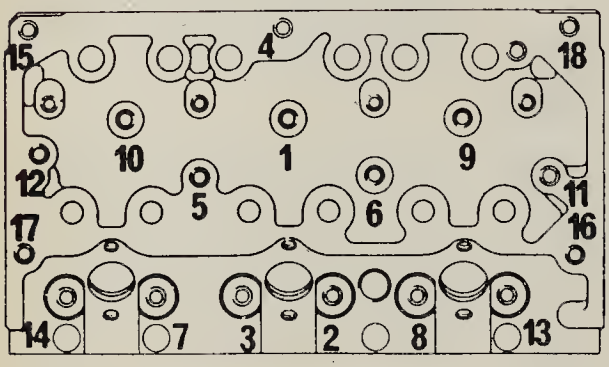


Fig. PR1-5—Cylinder head tightening sequence for all engines except 3.152 engine.

engines, clearance should be 0.30 mm (0.012 inch) for both intake and exhaust valves. On 3.1522, 3.1524 and T3.1524 engines, clearance should be 0.20 mm (0.008 inch) for exhaust valves and 0.32 mm (0.0125 inch) for intake valves.

To adjust valve clearance on engines equipped with a TDC mark on flywheel, turn crankshaft until TDC mark is in center of flywheel housing inspection hole and number 1 piston is on compression stroke (both valves closed). Check and adjust clearance as necessary on valves 1, 2, 3 and 5 (number 1 valve at front). Turn crankshaft one complete revolution until TDC mark is again visible in inspection hole, then adjust clearances for number 4 and 6 valves.

To adjust valves on engines not equipped with a TDC mark, first turn crankshaft until intake valve for number 1 cylinder is opening and the exhaust valve is closing. Check and adjust clearances on number 4 and 6 valves. Place temporary marks on crankshaft and on adjacent point on front cover, then turn crankshaft one complete revolution until marks are realigned. Check and adjust clearances on valves 1, 2, 3 and 5.

CYLINDER HEAD

To remove cylinder head, drain coolant and disconnect radiator hose from thermostat housing. Detach cold starting connections. Disconnect and remove fuel lines and injectors. Plug all fuel system openings to prevent entry of dirt. Disconnect oil pipe from cylinder head and remove intake pipe, exhaust pipe and turbocharger (if so equipped). Remove rocker arm cover, then remove rocker arm assembly and oil pipe. Remove cylinder head retaining nuts and cap screws in reverse order of tightening sequence shown in Fig. PR1-4 or PR1-5. Lift off cylinder head assembly.

Clean cylinder head and inspect for wear and damage. Check mounting surface for distortion. If head is warped more than 0.08 mm (0.003 inch) crosswise or 0.15 mm (0.006 inch) lengthwise, mounting surface should be remachined. On 3.152 engine, material may be removed as necessary as long as overall head thickness is not reduced below 75.69 mm (2.980 inches). On all other engines, a maximum of 0.30 mm (0.012 inch) may be removed providing nozzle protrusion (N–Fig. PR1-3) does not exceed 4.67 mm (0.184 inch) on D3-152 engine or 6.32 mm (0.249 inch) on 3.1522, 3.1524 and T3.1524 engines.

NOTE: Shim washers or extra nozzle seal washers must not be used to reduce nozzle projection.

After head surface has been machined, check valve head depths as outlined in VALVE SYSTEM section and correct to specifications if necessary.

To reinstall cylinder head, proceed as follows: Cylinder head and crankcase surfaces must be clean. Do not use any gasket sealing compounds on cylinder head gasket. Different methods of retaining the cylinder head have been used. On early 3.152 and D3.152 engines, studs and nuts were used to secure cylinder head. On these engines, refer to appropriate tightening sequence shown in Fig. PR1-4 or PR1-5 and tighten retaining nuts in steps to 81 N·m (60 ft.-lbs.). On late 3.152 engines, the studs were replaced by cap screws except for the six used at position 13, 6, 2, 3, 7 and 12 in Fig. PR1-4. On late D3.152 engines, all but two of the studs (13 and 14–Fig. PR1-5) were replaced by cap screws of three different lengths. The four shortest 82.5 mm (3¼ inches) screws are used at positions 7, 3, 2 and 8; the mid-length 92 mm (3⅝ inches) screws should be at positions 15, 4 and 18; and the longest 98.4 mm (3⅞ inches) are used at remaining positions. On all engines with both nuts and cap screws, tighten in steps following sequence shown in Fig. PR1-4 or PR1-5 to 95 N·m (70 ft.-lbs.). On 3.1522, 3.1524 and T3.1524 engines, studs are used at positions 13 and 14 (Fig. PR1-5) and also at positions 4, 15 and 18 (some early engines have cap screws at these three positions). Two different lengths of cap screws are used–the shorter screws are used at positions 2, 3, 7 and 8 and the longer screws are used at remaining positions. Nuts and cap screws should be tightened in steps following sequence shown in Fig. PR1-5 to a final torque of 95 N·m (70 ft.-lbs.).

Reinstall rocker arm shaft assembly. Before tightening retaining nuts on early engines, be sure slot in front end of rocker shaft (Fig. PR1-6) is positioned as shown (pointing towards sharp corner at

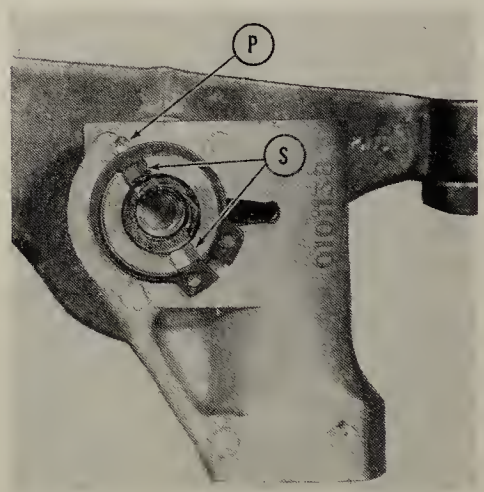


Fig. PR1-6—On early engines, slot (S) in end of rocker arm shaft should be positioned so it is pointing towards sharp corner at top of bracket (P). On late engines, slot is removed and shaft is correctly located by a dowel through one of the brackets.

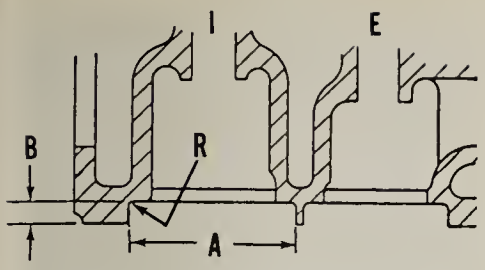


Fig. PR1-7—View of valve seat insert counterbore for engines so equipped. Refer to text for specified dimensions.

tip of bracket). This will ensure correct lubrication of shaft assembly. On late engines, the slot has been removed and shaft is correctly positioned by a dowel through one of the mounting brackets. Complete installation by reversing the removal procedure.

Operate engine until normal operating temperature is reached. Then, while engine is hot, remove rocker shaft assembly and injectors. Retighten nuts and cap screws in recommended sequence to specified torque. If a nut or cap screw does not turn before specified torque is reached, loosen 1/12 to 1/6 of a turn, then retighten to specified torque. After retightening all nuts and screws, recheck the first 10 positions (without loosening) to be certain they are still at correct torque. Reinstall removed components and readjust valve clearance.

VALVE SYSTEM

All 3.152 engines have 45° valve face and seat angles. Early D3.152 engines (prior to engine number U584638F) have 45° face and seat angles, except for some engines rated above 2250 rpm which have 35° face and seat angles. Late D3.152 engines and all 3.1522, 3.1524 and T3.1524 engines have 35° face and seat angles.

When reconditioning valves and seats, do not remove any more material than necessary, otherwise, valve recession (distance valve head is below surface of cylinder head) may exceed the specified limit. Specified valve recession is 1.68-3.50 mm (0.066-0.140 inch) for 3.152 engines. On D3.152 engines with 45° seats, valve recession should be 1.50-2.13 mm (0.059-0.084 inch) for intake and 1.47-2.13 mm (0.058-0.084 inch) for exhaust. On D3.152 engines with 35° seats, valve recession should be 1.32-1.83 mm (0.054-0.072 inch) for intake and 1.60-2.11 mm (0.063-0.083 inch) for exhaust. On all 3.1522, 3.1524 and T3.1524 engines, valve recession should be 1.32-1.75 mm (0.052-0.069 inch) for intake and 1.60-2.18 mm (0.063-0.086 inch) for exhaust.

Renewable valve seat inserts are used on intake and exhaust for 3.152 engines and on exhaust only on D3.152 engines with 45° seats. When renewing valve seat inserts, new valve guides should also be installed to ensure accurate machining of cylinder head counterbore. Using suitable cutters, refer to Fig. PR1-7 and machine cylinder head to the following dimensions:

Intake—3.152

Depth (B)	6.30-6.35 mm (0.248-0.250 in.)
Diameter (A)	47.60-47.62 mm (1.874-1.875 in.)
Radius (R)	1.02-1.30 mm (0.040-0.050 in.)

Exhaust—3.152

Depth (B)	6.30-6.35 mm (0.248-0.250 in.)
Diameter (A)	41.25-41.28 mm (1.624-1.625 in.)
Radius (R)	1.02-1.30 mm (0.040-0.050 in.)

Exhaust—D3.152

Depth (B)	7.87-7.92 mm (0.310-0.312 in.)
Diameter (A)	42.62-42.64 mm (1.678-1.679 in.)
Radius (R)—max.	0.38 mm (0.015 in.)

Valve seat inserts should be pressed (not hammered) squarely into cylinder head counterbores using the valve guides as a pilot. Inserts must bottom firmly in counterbore. On D3.152 engines, machine a 30° flare to a depth of 3.3-3.5 mm (0.130-0.138 inch), measured at inner diameter of exhaust insert. Machine all seats as required to recess valve the recommended distance from cylinder head gasket surface.

All engines are equipped with renewable valve guides. Inside diameter of guides should be 7.98-8.01 mm (0.3141-0.3155 inch). Valve stem outer diameter is 7.90-7.92 mm (0.311-0.312 inch). Desired operating clearance of valves in guides is 0.05-0.11 mm (0.0021-0.0045 inch). Maximum allowable clearance is 0.152 mm (0.006 inch) for intake and 0.14 mm (0.0055 inch) for exhaust. Guides should have interference fit in cylinder head of 0.04-0.08 mm (0.0016-0.0031 inch).

When renewing guides on 3.152 and D3.152 engines, note that both ends of guides are chamfered, one 20° and the other 45°. Be sure to install guides with 45° chamfer end towards top of head. Press in until end of guide protrudes 14.73-15.09 mm (0.580-0.594 inch) above spring seating surface of head.

When renewing valve guides on 3.1522, 3.1524 and T3.1524 engines, note that intake guides are shorter than exhaust guides and are not interchangeable. The inside diameter of both guides is counterbored at one end and this end must be installed towards the valve seat. Press guides in from the top of head until top of intake guide protrudes 9.19-9.55 mm (0.362-0.376 inch) above spring seating surface of head and exhaust guide protrudes 14.73-15.09 mm (0.580-0.594 inch) above spring seating surface.

Inspect rocker arms and shaft for excessive wear and other damage. Be sure to identify parts in order of removal so they can be reinstalled in their original positions. Rocker shaft diameter is 15.81-15.84 mm (0.6223-0.6238 inch). Rocker arm bore diameter is 15.86-15.89 mm (0.6244-0.6256 inch). Desired operating clearance of rocker arms on shaft is 0.02-0.09 mm (0.0008-0.0035 inch) and maximum allowable clearance is 0.13 mm (0.005 inch). Rocker arm bushings are not renewable. When reassembling rocker arm assembly, be sure slot in end of shaft (early engines) will be towards front of engine. Refer to Fig. PR1-6 for proper position of slot. On late engines, shaft is correctly located by a dowel through one of the rocker shaft brackets and slot has been removed from end of shaft.

The valve tappets operate in bores in the cylinder head. Outside diameter of tappets when new is 15.81-15.84 mm (0.6225-0.6236 inch) and inside diameter of bores in cylinder head is 15.86-15.90 mm (0.6244-0.6260 inch). Desired operating clearance of tappets in cylinder head bores is 0.02-0.09 mm (0.0008-0.0035 inch).

On some engines, two valve springs (inner and outer) are used on the intake valves. One spring is used on exhaust valves. Exhaust valve spring and intake valve outer spring free length should be 45.29-45.80 mm (1.783-1.803 inches). Spring test load is 9.45-11.25 kg (20.75-24.75 pounds) when compressed to a length of 38.10 mm (1.5 inches). Inner valve spring (if so equipped) free length should be 34.67-35.69 mm (1.365-1.405 inches). Inner spring test load is 3.18-4.08 kg (7-9 pounds) when compressed to a length of 30.16 mm (1.1875 inches). Renew springs if they fail to meet specifications or if they are rusted or distorted.

COOLING SYSTEM

The engine coolant is circulated by a centrifugal type pump mounted on the front of timing gear cover. The pump is belt driven from the engine crankshaft. After renewing the drive belt, it is recommended that belt tension be rechecked after the first two hours of operation. Adjust tension so belt deflects about 10 mm (3/8 inch) when

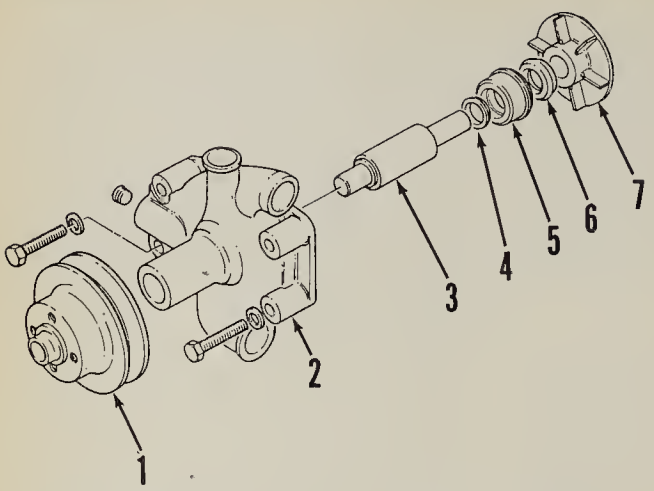


Fig. PR1-8—Exploded view of typical water pump.
1. Fan hub & pulley
2. Pump housing
3. Shaft & bearing assy.
4. Thrower
5. Seal
6. Ceramic seat
7. Impeller

depressed with moderate thumb pressure at a point midway between water pump and alternator pulleys.

A thermostat is mounted in the cylinder head water outlet. The bellows type thermostat should start to open at 77°-82°C (170°-180°F) and be fully open at 98°C (208°F).

To overhaul water pump, first remove pump pulley (1–Fig. PR1-8) using a suitable puller. Press pump shaft with bearings out through rear of pump housing. Press shaft out of impeller (7). Remove ceramic seat (6), seal (5) and thrower (4).

Pump shaft and bearing assembly is renewed as a unit. Press shaft (shorter end first) into rear of pump housing until front end of bearing is flush with front surface of pump housing. Assemble thrower onto shaft. Install seal with carbon face to rear and install ceramic seat with ceramic insert toward seal. Support front end of pump shaft, then press impeller onto shaft until clearance (C–Fig. PR1-9 or PR1-10) of 0.25-0.51 mm (0.010-0.020 inch) is obtained between impeller blades and pump body. Support rear end of shaft (not the impeller), then press fan pulley onto shaft until front end of pulley is flush with front end of shaft (Fig. PR1-9); or if fan mounting hub projects forward from pulley, press pulley on until fan mounting surface is 140.49 mm (5.531 inches) from rear surface of pump housing (D–Fig. PR1-10).

INJECTOR

When removing injectors, it is of utmost importance to plug all openings in fuel system to prevent entry of dirt. Be sure to remove copper washer from bottom of injector bore in cylinder head.

Thoroughly clean cylinder head bore and injector nozzle before reinstalling injector. It is recommended that copper seal washer and rubber dust seal be renewed whenever injectors are removed. A thin metal heat shield is used around the injectors on 3.1522 engine. The head shield must be renewed whenever the injector is removed. Tighten injector mounting nuts evenly to 16 N·m (12 ft.-lbs.).

TESTING. A special nozzle test pump is required to test and adjust injectors. The injector should be checked for specified opening pressure, nozzle leakage and correct spray pattern.

WARNING: Fuel leaves the injector nozzle with sufficient force to penetrate the skin. When testing, keep yourself clear of nozzle spray.

Connect injector to nozzle test pump, then operate tester lever several quick strokes to purge air from injector and to make sure nozzle valve is not stuck. Then operate tester lever slowly while noting nozzle opening pressure reading on tester gage. The specified opening pressure can be determined by referring to the injector code letters stamped on the injector body and the following table.

Code letters	Opening Pressure
3.152 Engines	
DD, DE	12160-12665 kPa (1765-1840 psi)
GC	17225-18745 kPa (2500-2720 psi)
D3.152 Engines	
BV, CR, CS	17225-18745 kPa (2500-2720 psi)
DF	17225-17730 kPa (2500-2570 psi)
DN, FS*, GW, UB	17225-18745 kPa (2500-2720 psi)
EE	17730-19250 kPa (2570-2790 psi)
GM	17730-18745 kPa (2570-2720 psi)
3.1522 Engines	
GS	23810-25330 kPa (3455-3675 psi)

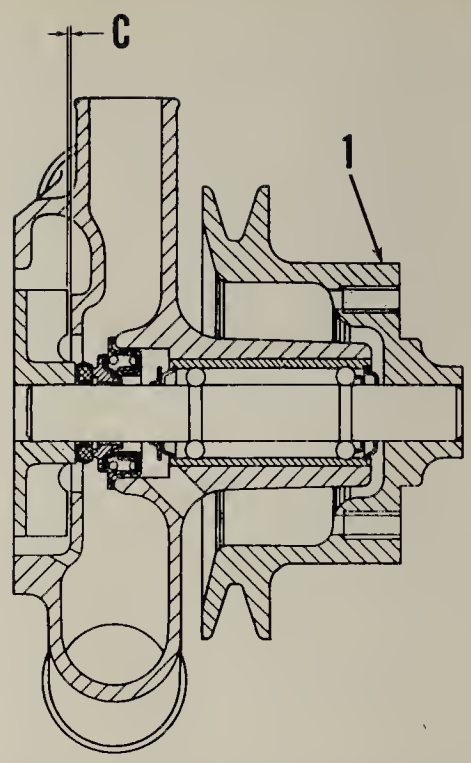


Fig. PR1-9—When reassembling, press impeller onto shaft until clearance (C) is 0.25-0.51 mm (0.010-0.020 inch). Fan hub (1) should be pressed on until flush with end of shaft.

3.1524 Engines	
EE	24320-25840 kPa (3530-3750 psi)
T3.1524 Engines	
HN	24320-25840 kPa (3530-3750 psi)

*When servicing "FS" injectors, they should be converted to "DN" type by installing appropriate nozzle valve assembly.

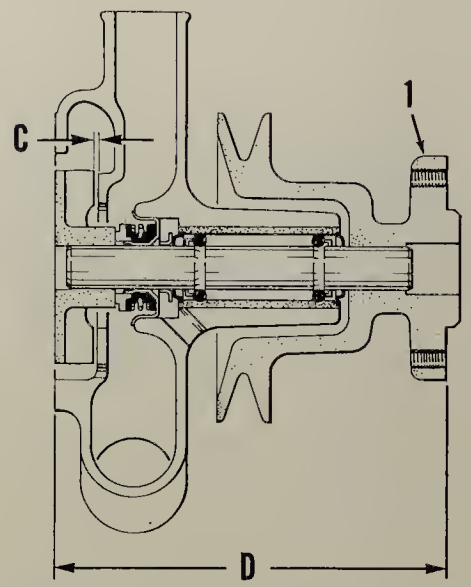


Fig. PR1-10—If equipped with fan hub (1) that extends forward from pulley, press hub on until dimension (D) is 140.49 mm (5.531 inches). Impeller clearance (C) should be 0.25-0.51 mm (0.010-0.020 inch.)

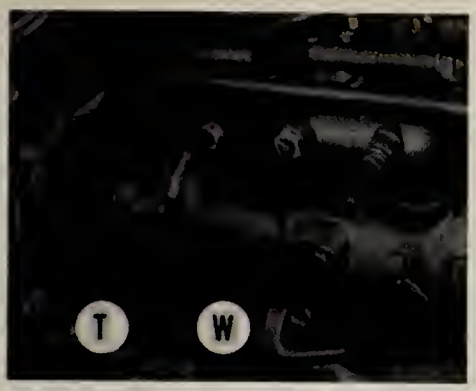


Fig. PR1-11—When installing fuel injection pump, align scribe marks (T) on pump flange and rear of timing gear housing. Pump timing marks are located behind cover (W).

To check nozzle for leakage, operate tester lever slowly to maintain pressure at 2000 kPa (300 psi) below opening pressure and observe tip for leakage. If a drop falls from nozzle tip within a 10 second period, nozzle valve is not seating and injector should be overhauled or renewed. During this test, be careful not to confuse fuel leaking from leak-off fitting at top of injector with leakage at nozzle tip.

To check spray pattern, operate the tester lever several quick strokes (about one stroke per second). Spray should be uniform and well atomized and nozzle should produce a "chatter" sound when operating properly.

INJECTION PUMP

A C.A.V. type D.P.A. fuel injection pump is used on all engines. It is recommended that injection pump be tested and serviced only by a shop qualified in diesel fuel injection repair.

To remove injection pump, disconnect and remove fuel lines from pump and immediately plug all openings. Disconnect speed control and shut-off control linkage at the pump. Remove cover plate from front of timing gear cover. On early 3.152 and D3.152 engines, remove inspection plate from side of timing gear cover and wedge injection pump drive gear in position to prevent it from moving out of mesh with idler gear. All other engines have a lug in gear case which holds gear in position when retaining screws are removed.

CAUTION: Do not turn crankshaft with fuel pump removed as damage could result to timing gear case and gears.

Remove pump gear mounting cap screws being careful not to drop them into timing case. Remove the injection pump mounting stud nuts, then withdraw the pump from rear of timing gear case.

To reinstall injection pump, align slot in pump shaft with dowel in drive gear and position pump on rear of timing case. Install pump stud nuts finger tight. Secure drive gear to pump shaft with the three cap screws. Adjust pump position until scribe line on pump flange is aligned with scribe line on rear of timing gear housing (T–Fig. PR1-11), then tighten stud nuts securely. Complete installation and bleed air from system. If pump was renewed, check and adjust maximum no-load speed as outlined in MAINTENANCE section.

FUEL LIFT PUMP

The lift pump is a diaphragm type which is actuated by the engine camshaft. To check pump output, disconnect the fuel outlet line and install a 0-70 kPa (0-10 psi) pressure gage to pump outlet. Crank engine for 10 seconds and note gage pressure reading. If pressure is less than 31 kPa (4.5 psi), pump is defective. Also, note time required for pump pressure to drop to one half of reading obtained when engine was being cranked. If time is less than 30 seconds, pump is defective. Individual parts are available for pump repair.

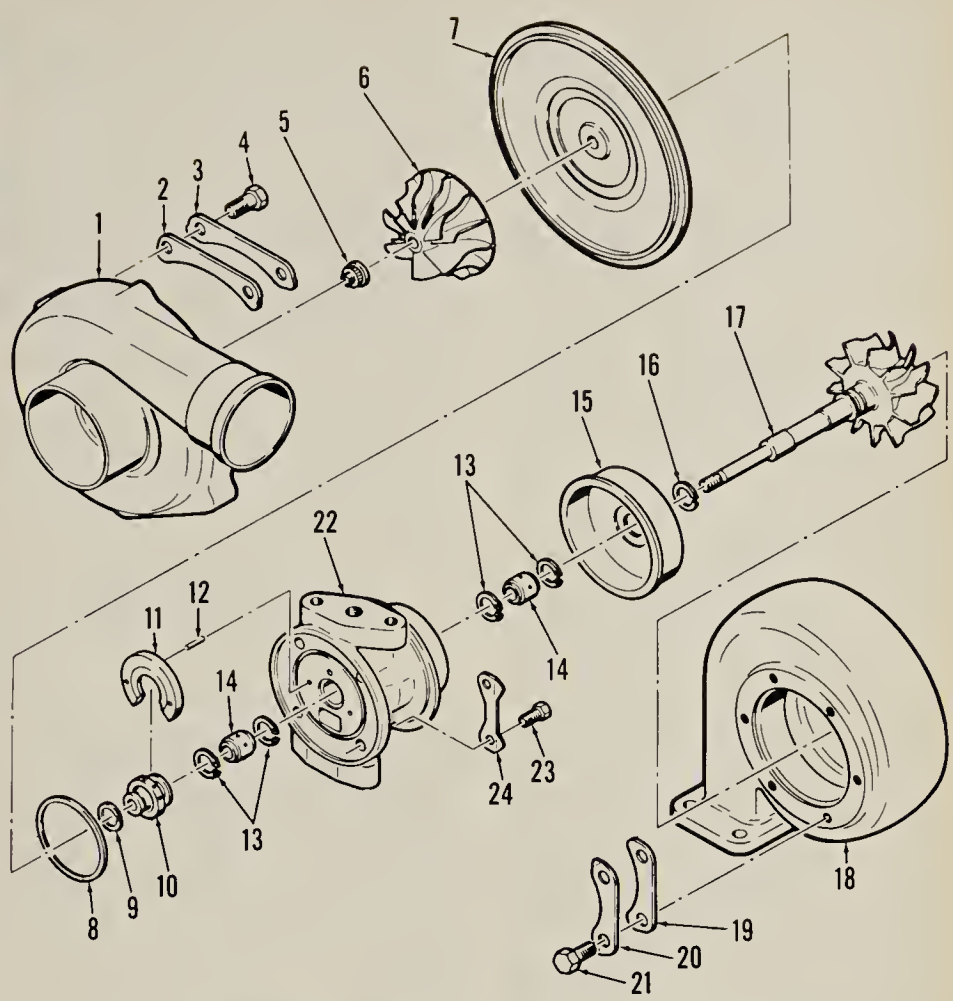


Fig. PR1-12—Exploded view of AiResearch T-31 turbocharger.

1. Compressor housing
2. Clamp
3. Lockplate
4. Cap screw
5. Nut
6. Compressor wheel
7. Backplate
8. Seal ring
9. Piston ring
10. Thrust collar
11. Thrust bearing
12. Spring pin
13. Snap ring
14. Bearing
15. Turbine wheel shroud
16. Piston ring
17. Turbine wheel & shaft
18. Turbine housing
19. Clamp
20. Lockplate
21. Cap screw
22. Center housing
23. Cap screw
24. Lockplate

TURBOCHARGER

Model T3.1524

An AiResearch T-31 turbocharger is used. To ensure satisfactory turbocharger operation, it is important that turbocharger receives adequate engine lubricating oil pressure, minimum 207 kPa (30 psi), and a clean supply of inlet air. Maximum boost pressure should be 41 kPa (6 psi) when engine is running at maximum speed and full load.

To disassemble turbocharger, first scribe match marks across compressor housing, center section and turbine housing for reassembly purposes. Remove compressor and turbine housings (1 and 18–Fig. PR1-12) being careful not to damage compressor or turbine wheel blades. Bent or cracked

blades cannot be repaired. Use a T-handle wrench to remove compressor wheel retaining nut to prevent possible bending of shaft. Remove compressor wheel (6), then withdraw turbine wheel and shaft assembly (17) from center section (22). Remove backplate (7) and thrust bearing (11). Remove outer retaining rings (13) and bearings (14) from center section. Remove and discard seal rings.

Inspect parts for signs of damage, corrosion and wear. Compressor and turbine must not show signs of rubbing, damage from foreign material, cracks or excessive wear. Clean parts in non-caustic carbon solvent. Renew all parts in which there is any doubt about serviceability. Always renew "O" ring, seal rings, bearing retaining rings, shaft bearings, compresson wheel locknut, turbine housing bolts and lock plates.

To reassemble, install bearings and retaining rings in center section and lubricate with clean oil. Position turbine shaft with seal ring into center section. Assemble thrust bearing (11) over thrust collar (10). Install seal ring on thrust collar, then position thrust collar over shaft so bearing is flat against housing and engages housing locating pins. Install seal ring in groove of housing, then install backplate with thrust spring over shaft, thrust collar and seal ring. Tighten backplate cap screws to 8.9 N·m (79 in.-lbs.) and secure with lock plates. Install compressor wheel. Oil threads of locknut and tighten to 2.26 N·m (20 in.-lbs.). Then, use a T-handle wrench to further tighten nut until shaft length increases by 0.14-0.16 mm (0.0055-0.0065 inch). If equipment is not available to measure shaft stretch, this alternate tightening method may be used: After tightening nut to 2.26 N·m (20 in.-lbs.), continue to tighten nut through an angle of 110 degrees. Install compressor housing while aligning match marks made prior to disassembly. Tighten mounting screws to 14 N·m (130 in.-lbs.). Install turbine housing while aligning match marks on housing and center section. Tighten mounting screws to 14 N·m (130 in.-lbs.). Be sure rotating assembly turns freely and does not contact housings.

When reinstalling turbocharger, connect oil drain pipe, then pour clean engine oil into oil inlet port of center housing while turning shaft assembly by hand to lubricate bearings. Connect air inlet and outlet pipes and exhaust pipe. With oil supply pipe loose and fuel pump control in stop position, crank engine with starter motor until oil flows from oil supply pipe. Connect oil pipe to center section. Start engine and run at idle speed for about five minutes to allow lubricating oil to flow before increasing engine speed or load.

PISTON, PISTON PIN AND RINGS

The pistons can be removed from the top after removing cylinder head, oil pan, oil pump and connecting rod caps. Be sure to remove ring ridge or carbon deposits from top of cylinders before attempting to remove pistons. The pistons are marked 1, 2 or 3 on piston crown, number 1 being at front of engine. Be sure to keep pistons and connecting rods together as assemblies for proper reassembly.

Piston pins are retained in pistons by two snap rings. Heating piston to about 38°-49°C (100°-120°F) will ease removal and installation if pin is tight. Manufacturer recommends renewing snap rings during reassembly if they have been in service for a long period of time. Piston pin diameter is 31.744-31.750 mm (1.2498-1.2500 inches) and bore diameter in piston is 31.747-31.753 mm (1.2499-1.2501 inches). Pin is a transition fit in piston.

Piston ring end gap is measured with ring positioned squarely in cylinder bore. Refer to the following table for specified end gap values.

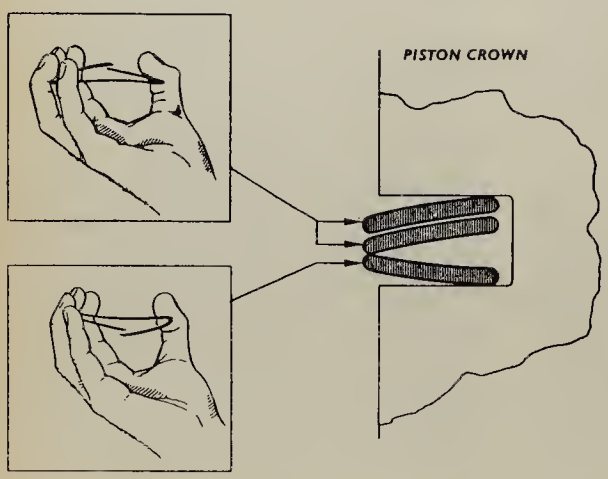


Fig. PR1-13—View showing correct installation of three-segment laminated compression ring used on some early engines.

3.152 Engine with Chromed Liners
All rings . . . . . 0.28-0.61 mm (0.011-0.024 in.)
3.152 Engine with Cast Iron Liners and D3.152 Engines Rated Up to 2250 Rpm
Top ring . . . . . 0.36-0.76 mm (0.014-0.030 in.)
2nd ring and slotted scraper . . . . . 0.28-0.69 mm (0.011-0.027 in.)
D3.152 Engine Rated Above 225 Rpm
Top and 4th rings . . . . . 0.36-0.69 mm (0.014-0.027 in.)
2nd and 3rd rings . . . . . 0.28-0.61 mm (0.011-0.024 in.)
AD3.152 Engine (Up-rated)
Top ring . . . . . 0.36-0.69 mm (0.014-0.027 in.)
2nd and 3rd rings . . . . . 0.28-0.61 mm (0.011-0.024 in.)
4th ring . . . . . 0.25-0.74 mm (0.010-0.029 in.)
3.1522, 3.1524 and T3.1524 Engines
Top ring . . . . . 0.30-0.74 mm (0.012-0.023 in.)
2nd and 3rd rings . . . . . 0.20-0.64 mm (0.008-0.025 in.)
Oil control ring . . . . . 0.25-0.76 mm (0.010-0.030 in.)

Inspect piston for wear and other damage. Renew piston if scoring is evident on piston skirt. Clean and inspect piston ring grooves for wear. Refer to the following table for specified ring groove and ring side clearance values.

3.152 and D3.152
Ring groove width:
Top and 2nd . . . . . 2.43-2.46 mm (0.0957-0.0968 in.)
3rd . . . . . 3.23-3.25 mm (0.1272-0.1279 in.)
4th and 5th . . . . . 6.40-6.43 mm (0.2520-0.2531 in.)
Ring clearance in groove:
Top . . . . . 0.05-0.10 mm (0.0020-0.0039 in.)
Maximum . . . . . 0.18 mm (0.007 in.)
2nd, 4th and 5th . . . . . 0.05-0.10 mm (0.0020-0.0039 in.)
AD3.152 Engine
Ring groove width:
Top, 2nd and 3rd . . . . . 2.43-2.46 mm (0.0957-0.0968 in.)
4th . . . . . 4.81-4.84 mm (0.1894-0.1905 in.)
Ring clearance in groove:
Top . . . . . 0.05-0.10 mm (0.0020-0.0039 in.)
Maximum . . . . . 0.18 mm (0.007 in.)
2nd and 3rd . . . . . 0.05-0.10 mm (0.0020-0.0039 in.)
4th . . . . . 0.05-0.11 mm (0.0020-0.0043 in.)

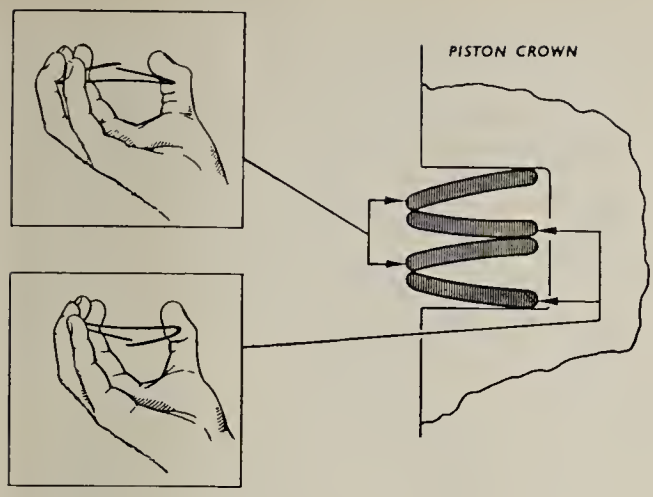


Fig. PR1-13A—View showing correct installation of four-segment, laminated compression ring used on some late production engines.

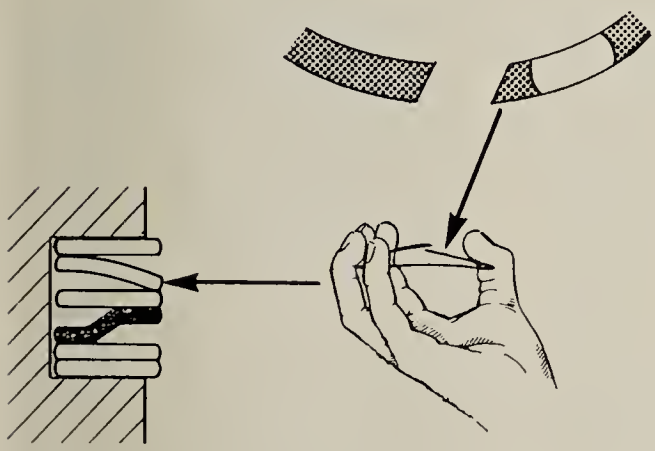


Fig. PR1-14—View showing correct installation of laminated oil scraper ring used on some engines.

3.1522, 3.1524 and T3.1524 Engines

Ring groove width:

Top and 2nd	2.43-2.46 mm (0.0957-0.968 in.)
Oil control	4.81-4.84 mm (0.1894-0.1905 in.)

Ring clearance in groove:

Top	0.05-0.10 mm (0.0020-0.0039 in.)
Maximum	0.18 mm (0.007 in.)
2nd and oil oil control	0.05-0.10 mm (0.0020-0.0039 in.)

Fit rings to pistons in the following positions (reading from top of piston):

3.152 Engine with Chrome Plated Liners.
1. Plain compression.
2. Taper face compression.*
3. Laminated compression.†
4. Slotted scraper.
5. Slotted scraper.

3.152 Engine with Cast Iron Liners and D3-152 and AD3.152 Engines Rated up to 2250 rpm.
1. Chrome plated compression.
2. Plain compression.
3. Laminated compression.†
4. Spring-loaded, laminated scraper or internal expander scraper.
5. Slotted scraper.

*One side of taper face compression ring is marked "T" or "TOP" and must be installed with this side facing upward.

†The laminated compression ring is composed of three segments on early engines or four segments on late engines. When assembling, be sure ring segments are positioned correctly as shown in appropriate Fig. PR1-13 or PR1-13A. The spring-loaded, laminated scraper ring must be assembled as shown in Fig. PR1-14. The internal expander type scraper ring (Fig. PR1-15) should be assembled as shown. Be sure the rail end gaps are equally spaced around the piston.

D3.152 Engines Rated Above 2250 rpm.
1. Chrome plated compression.
2. Plain compression.
3. Internally stepped compression.
4. Coil spring loaded scraper.

AD3.152 Engine.
1. Chrome plated compression.
2. Internally stepped compression.
3. Internally stepped compression.
4. Coil spring loaded scraper.

3.1522 Engine.
1. Chrome compression.
2. Internally stepped compression.
3. Coil spring loaded scraper.

3.1524 and T3.1524 Engines.
1. Tapered face, chrome compression.
2. Tapered face, plain comression.
3. Coil spring loaded scraper.

When installing coil spring loaded scraper ring install coil spring first, then install ring over spring with ring end gap positioned 180° opposite from coil spring ends. When installing compression rings with internal step (notch), the stepped edge of ring should be towards top of piston.

If reinstalling original pistons, note that pistons are stamped 1, 2 or 3 and should be assembled on respective connecting rods stamped 1, 2 or 3 and installed in respective cylinder (number 1 at front). Be sure the letter "F", word "Front" or arrow mark on piston crown is towards front of engine and numbered side of connecting rod and cap is towards injection pump side of engine. If identification marks have been removed from piston crown, assemble piston to connecting rod so offset cavity in piston crown is towards side of rod marked with identification number. Mark front side of piston crown for future reference.

If installing new pistons, the correct piston height in relation to top surface of cylinder block must be maintained. With piston at top dead center, piston crown must be 0.00-0.13 mm (0.000-0.005 inch) below top surface of cylinder block for 3.152 engine; between 0.102 mm (0.004 inch) above to 0.025 mm (0.001 inch) below top of block for D3.152 engine; 0.03-0.15 mm (0.001-0.006 inch) below top of block for AD3.152 engine; between 0.03 mm (0.001 inch) above to 0.17 mm (0.0067 inch) below cylinder block surface for 3.1522 engine; and 0.025-0.152 mm (0.001-0.006 inch) below top of cylinder block on 3.1524 and T3.1524 engines. Pistons for 3.152, D3.152 and AD3.152 engines have extra material in the piston crown area which must be machined off to provide the correct piston height. On 3.1522, 3.1524

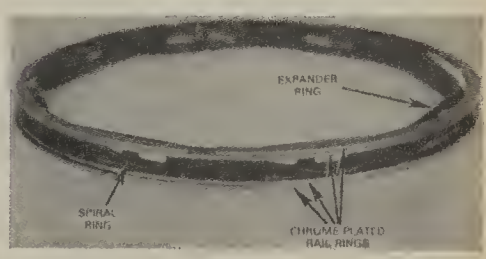


Fig. PR1-15—View of internal expander type oil scraper ring. Install internal expander first, then assemble two lower rails, spiral ring and two upper rails in that order.

and T3.1524 engines, three different height grades ("H' for high, "M" for medium and "L" for low) of pistons are used in production to obtain desired piston height. The grade letters are stamped on top of piston. Replacement pistons are stamped on top of piston. Replacement pistons are available in "H" and "L" grades. "H" grade pistons may be used to replace "M" or "L" grade pistons, but piston crown will have to be machined to obtain specified piston height.

When assembling new pistons to connecting rods, be sure offset cavity in top of piston is towards side of rod marked with cylinder identification numbers. Reinstall connecting rod and piston with numbered side of rod towards injection pump side of engine. Stamp top of pistons with appropriate cylinder number and front end identification for future reference.

CONNECTING ROD

The connecting rod uses a renewable bushing in small end. Use suitable installing tools when renewing bushings to prevent damage to bushing or rod. Be sure oil hole in bushing is aligned with oil hole in top of rod. Bushings must be reamed to final size after installation. Bushing inside diameter should be 31.76-31.79 mm (1.2505-1.2515 inches). Piston pin outer diameter is 31.744-31.750 mm (1.2498-1.2500 inches). Desired operating clearance of pin in bushing is 0.01-0.04 mm (0.0004-0.0016 inch).

A precision, insert type bearing is used in the connecting rod big end. Standard inside diameter of bearings is 57.19-57.21 mm (2.2515-2.2525 inches) and outside diameter of crankpins is 57.11-57.13 mm (2.2485-2.2492 inches). Desired bearing running clearance is 0.06-0.10 mm (0.002-0.004 inch). Connecting rod big end side clearance on crankpin should be 0.24-0.50 mm (0.010-0.020 inch).

When reinstalling connecting rods, be sure side stamped with cylinder identification number is toward injection pump side of engine. Manufacturer recommends renewing connecting rod cap nuts whenever they are removed. Three types of connecting rod nuts have been used on 3.152, D3.152 and AD3.152 engines. The original nuts were self-locking. These were later replaced by cadmium plated (bright finish) nuts which have been replaced in latest engines which phosphated (dull black finish) nuts. Model 3.1522, 3.1524 and T3.1524 engines used only cadmium plated and phosphated nuts. The nuts should be tightened to the following torque values: 95 N·m (70 ft.-lbs.) for self-locking nuts, 61 N·m (45 ft.-lbs.) for cadmium plated nuts and 81 N·m (60 ft.-lbs.) for phosphated nuts.

CYLINDER BLOCK AND LINERS

The cylinder block is equipped with renewable thin wall, dry type cylinder liners. Model 3.152 and D3.152 engines are equipped with cast iron or chrome plated liners. All other engines use cast iron liners. Cast iron and chrome plated liners are not interchangeable due to difference in liner flange dimensions.

Production liners are an interference fit in cylinder bores. Service replacement liners are a transitional fit in cylinder block and are prefinished so no machining is required after installation. If desired, unbored cast iron, production style liners (with interference fit in cylinder block) are available for service installation. These liners must be bored and honed to correct size after installation. Liners with oversize outside diameter are available for installation in cylinder block when the standard block bore must be enlarged to remove damage. These liners are available in chromed, prefinished, 0.13 mm (0.005 inch) oversize and cast iron, unbored 0.25 mm (0.010 inch) oversize. When an oversize liner is used, the oversize amount should be stamped on top of cylinder block between the liner and side of block for future reference.

When removing and installing cylinder liners, use suitable tools to prevent damage to cylinder block or liners. Special tool 21825052 and adapter 21825054 are available from manufacturer for this purpose. Be sure cylinder block bore and liner outside diameter are thoroughly clean before proceeding with installation.

Shims are available for installation under liner flange, if necessary, to obtain recommended liner installed height. Before installing liner, measure flange thickness and cylinder block counterbore depth to determine shim thickness required to adjust liner flange height. Shims are 0.13 mm (0.005 inch) thick. Depth of counterbore for chrome liner flange should be 1.17-1.24 mm (0.046-0.049 inch) and for cast iron liner flange, depth should be 3.76-3.86 mm (0.148-0.152 inch). On 3.152 and D3.152 engines with chromed liners, top of liner flange should be 0.02-0.18 mm (0.001-0.007 inch) below surface of cylinder block when properly installed. On all engines with cast iron liners, top of flange should be between 0.10 mm (0.004 inch) above to 0.10 mm (0.004 inch) below top surface of block.

Cylinder block bore should be 93.66-93.69 mm (3.6875-3.6885 inches). Production style liners should have a 0.03-0.08 mm (0.001-0.003 inch) interference fit in block. Service liners should have a 0.03 mm (0.001 inch) loose to 0.03 mm (0.001 inch) tight transition fit in block. Inside diameter of a finished production liner should be 91.48-91.50 mm (3.6015-3.6025 inches) and inside diameter of service liner should be 91.50-91.53 mm (3.6025-3.6035 inches). Renew liner if bore wear exceeds 0.178 mm (0.007 inch).

On some engines, restriction plugs are installed in some of the water passages in the top of cylinder block. If plugs are removed, be sure correct size of plug (Fig. PR1-16) is reinstalled in correct hole as shown. Plugs must be flush with top surface of cylinder block. Front plug, if renewed, will require machining prior to installation to fit flush with top surface of block.

TIMING GEARS AND FRONT COVER

To remove timing gear cover, drain coolant and disconnect hose from water pump. Remove fan belt, water pump, alternator and alternator brackets and crankshaft front pulley. Remove cover mounting cap screws and withdraw cover.

The crankshaft front oil seal (12 – Fig. PR1-17) is located in the front cover (11)

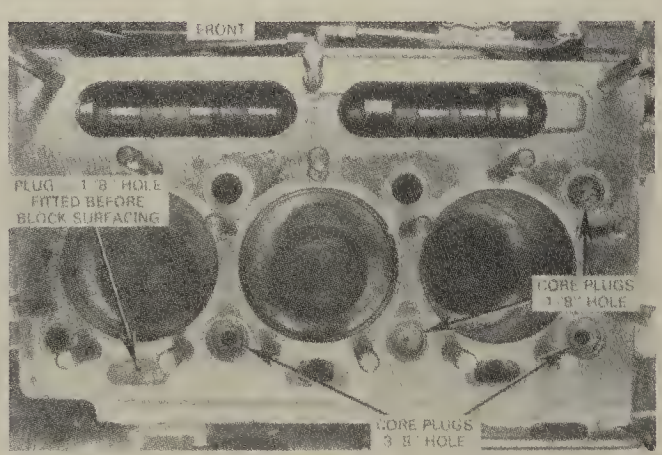


Fig. PR1-16—If coolant restriction plugs in top of cylinder block are removed, be sure correct size of plug is installed in correct water passage as shown.

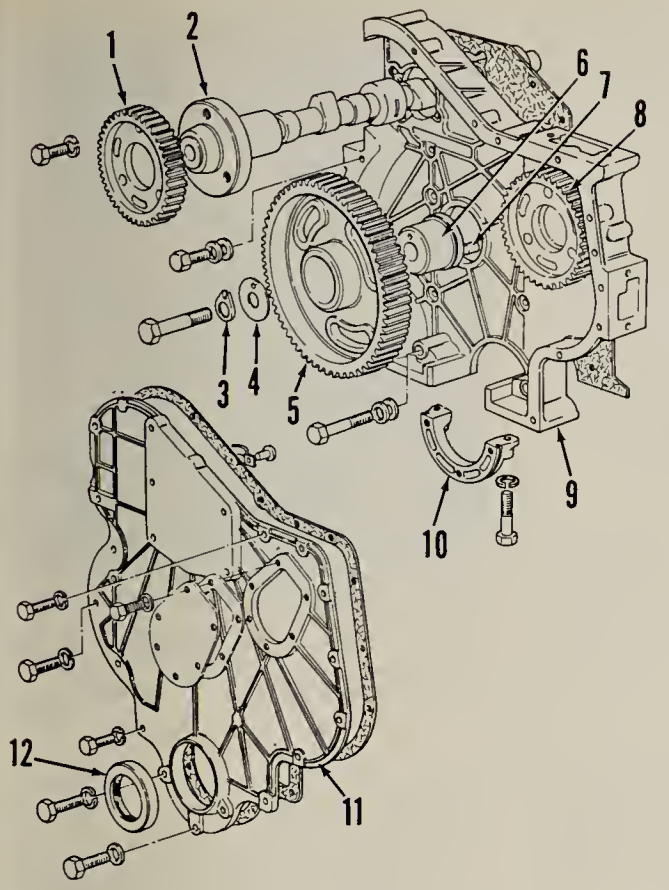


Fig. PR1-17—Exploded view of timing gears, housing and cover used on 3.1522 engine. Other engines are similar.

1. Camshaft gear
2. Camshaft
3. Locking washer
4. Retainer washer
5. Idler gear
6. Idler stub shaft
7. Locating dowel
8. Injection pump gear
9. Housing
10. Bottom cover
11. Front cover
12. Crankshaft oil seal

and may be renewed at this time. Early engines were equipped with a black nitrile seal and a crankshaft oil thrower. Later engines used a red silicone seal and the oil thrower was replaced by a spacer. The oil thrower should not be used with later style seal. Current production engines use a black Viton type seal with a protruding lip at the front. Refer to Fig. PR1-17A. The new seal should be pressed into cover until front face of seal is distance (X) below outer surface of cover. On early engines (except AD3.152), distance (X) should be 16 mm (0.625 inch). On early AD3.152, distance (X) should be 11.43 mm (0.450 inch). On all late engines with black Viton seal, installed distance should be 9.35 mm (0.375). Be sure spring-loaded lip faces inward on all engines.

Inspect all gears for excessive wear and other damage and renew as necessary. When renewing gears be sure there is a minimum backlash of 0.08 mm (0.003 inch). Idler gear bushing bore diameter should be 53.98-54.02 mm (2.1252-2.1268 inches) and idler stub shaft diameter is 53.92-53.94 mm (2.1229-2.1236 inches). Clearance of gear on stub shaft should be 0.03-0.09 mm (0.0012-0.0035 inch). Idler gear end play should be 0.13-0.38 mm (0.005-0.015 inch) and maximum allowable end play is 0.46 mm (0.018 inch). Tighten idler gear retaining screw to 68 N·m (50 ft.-lbs.). Camshaft gear is a clearance fit on camshaft. When reinstalling gear, make certain "D" letters (D–Fig. PR1-18) stamped on end of camshaft and gear are adjacent to each other. Injection pump gear is a clearance fit on pump shaft and is correctly positioned by a locating dowel. Crankshaft gear is a transition fit on crankshaft and is properly positioned by a Woodruff key.

When reinstalling gears be sure timing marks (Fig. PR1-18) are aligned properly. When all marks are aligned, number 1 piston will be at TDC on the compression stroke.

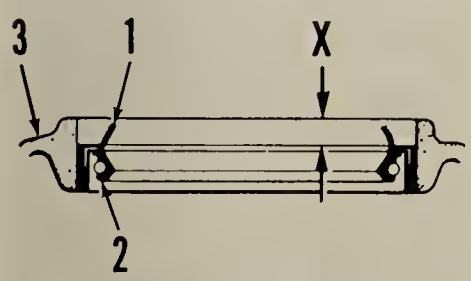


Fig. PR1-17A—Current production Viton type front crankshaft seal has a dust seal lip (1) protruding forward. Spring-loaded lip (2) must be facing inward. Refer to text for distance (X) that seal should be below outer surface of timing gear cover (3).

Fig. PR1-18—View of engine timing gear train. Timing marks must be aligned when engine is assembled. However, with gears installed, the marks will align only once every 18 crankshaft revolutions.

CAMSHAFT

The camshaft is supported at the front by a renewable bushing in the crankcase on some engines. All other camshaft journals operate directly in unbushed bores in crankcase.

To remove camshaft, first remove timing gear cover as previously outlined. Rotate crankshaft until marked teeth on crankshaft gear, idler gear and camshaft gear are aligned. Remove fuel transfer pump. Remove rocker shaft assembly, then raise tappets and support in raised position. Carefully withdraw camshaft and gear assembly from cylinder block.

Inspect camshaft for scoring or wear and renew if necessary. Front journal diameter is 47.47-47.50 mm (1.869-1.870 inches), center journal diameter is 47.22-47.24 mm (1.859-1.860 inches) and rear journal diameter is 46.71-47.74 mm (1.839-1.840 inches). Renew camshaft if journals are worn or out-of-round in ex-

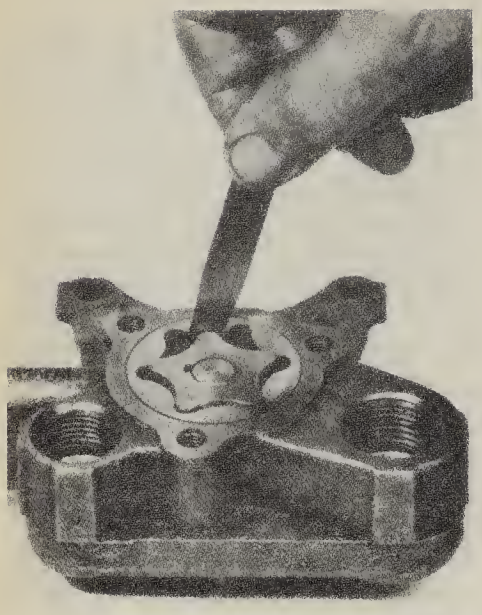


Fig. PR1-19—Use a feeler gage to check clearance between inner and outer oil pump rotors.

cess of 0.05 mm (0.002 inch). Inner diameter of front bushing (if used) should be 47.55-47.60 mm (1.872-1.874 inches) and running clearance should be 0.05-0.13 mm (0.002-0.005 inch). Cylinder block front bore diameter without bushing is 47.60-47.68 mm (1.874-1.877 inches) and running clearance should be 0.10-0.20 mm (0.004-0.008 inch). Crankcase bore for center journal is 47.35-47.42 mm (1.864-1.867 inches) and for rear journal is 46.84-46.91 mm (1.844-1.847 inches). Desired clearance for camshaft in either bore is 0.10-0.20 mm (0.004-0.008 inch).

If camshaft gear was removed, note that "D" marks (D – Fig. PR1-18) on end of camshaft and on gear must be adjacent to each other. To reinstall camshaft reverse the removal procedure. Be sure to align timing marks on gears. The camshaft end thrust is taken by a steel spring riveted to inside of timing gear cover.

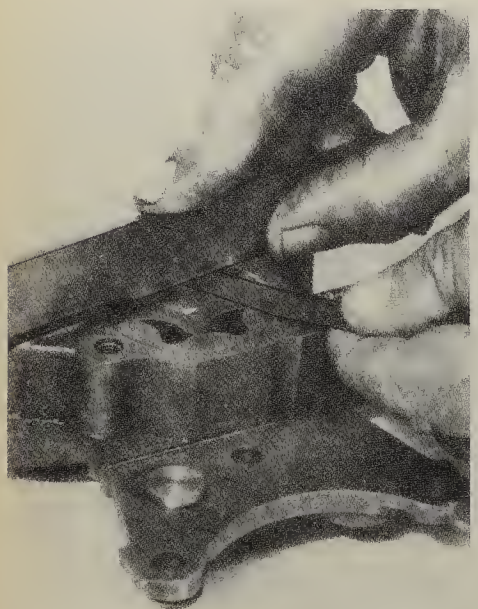


Fig. PR1-20—Pump rotor end clearance may be checked with a straightedge and feeler gage as shown.

OIL PUMP

The rotary type oil pump is mounted on front main bearing cap and is driven from the crankshaft gear thorough an idler gear. The oil pressure relief valve is located in the pump body. Normal oil pressure with engine at full speed and normal operating temperature is 207-414 kPa (30-60 psi). Relief valve opening pressure setting is 345-448 kPa (50-65 psi).

To remove oil pump, first drain oil and remove oil pan. Remove the small lower section of timing gear housing which extends below crankshaft. Remove idler gear. Disconnect pump discharge pipe. Remove mounting screws and withdraw pump assembly.

Remove pump end plate. Do not remove pump drive gear. Individual parts are not available for pump repair. If components fail to meet specified values, pump assembly must be renewed. Check rotor clearance with a feeler gage as shown in Fig. PR1-19. Check rotor end clearance with a straightedge and feeler gage as shown in Fig. PR1-20. Refer to the following table for desired clearance.

3.152, D3.152 and AD3.152 Engines

Pump Part Nos. 41314026, 41314046, 41314078
- Inner rotor to outer rotor . . . . . 0.01-0.06 mm (0.0005-0.0025 in.)
- Inner rotor end clearance . . . . . 0.04-0.08 mm (0.0015-0.0030 in.)
- Outer rotor end clearance . . . . . 0.01-0.06 mm (0.0005-0.0025 in.)

Pump Part Nos. 41314043, 41314079, 41314081
- Inner rotor to outer rotor . . . . . 0.03-0.15 mm (0.001-0.006 mm)
- Inner and outer rotor end clearance . . . . . 0.03-0.13 mm (0.001-0.005 in.)

Pump Part No. 41314124
- Inner rotor to outer rotor . . . . . 0.06-0.11 mm (0.0025-0.0045 in.)
- Inner and outer rotor end clearance . . . . . 0.03-0.08 mm (0.001-0.003 in.)

Fig. PR1-21—Note that main bearing caps are numbered and also marked with a serial number. When correctly installed, serial number on cap should be on same side as serial number stamped on bottom of cylinder block.

3.1522, 3.1524 and T3.1524 Engines
- Inner rotor to outer rotor . . . . . 0.06-0.11 mm (0.0025-0.0045 in.)
- Inner rotor end clearance . . . . . 0.04-0.09 mm (0.0015-0.0035 in.)
- Outer rotor end clearance . . . . . 0.03-0.08 mm (0.001-0.003 in.)

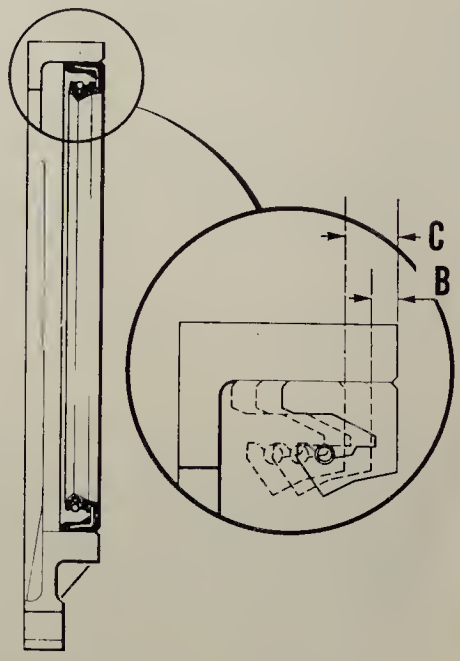


Fig. PR1-22—Early style crankshaft rear oil seal may be pressed further inward into rear housing to obtain a new seal contact area on crankshaft flange. Seal is installed flush with rear face of housing in production.
B. 3.2 mm (⅛ inch)
C. 6.4 mm (¼ inch)

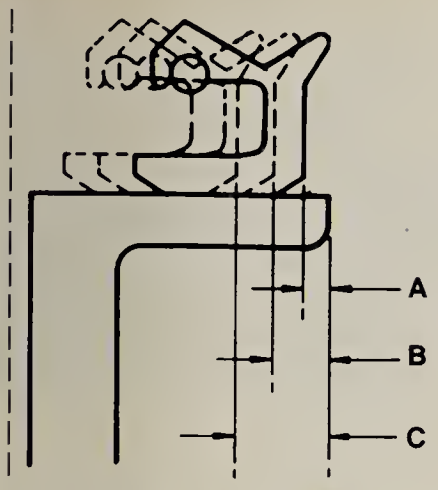


Fig. PR1-23—Late style rear oil seal has a dust seal lip protruding rearward. Spring-loaded lip must face inward. Seal may be installed in three different positions. Position "A" is production installation for late style seal.

A. 2.2 mm (3/32 inch)
B. 4.6 mm (3/16 inch)
C. 6.9 mm (9/32 inch)

Inspect oil pump idler gear and shaft for wear and other damage. Inside diameter of gear bushing when new is 16.67-16.69 mm (0.6563-0.6570 inch). Outer diameter of stub shaft should be 16.63-16.64 mm (0.6548-0.6553 inch). Desired running clearance of gear on shaft is 0.02-0.06 mm (0.0008-0.0024 inch). Gear end play should be 0.20-0.58 mm (0.008-0.023 inch).

CRANKSHAFT AND BEARINGS

The crankshaft operates in four renewable main bearings. The bearings are precision insert type. Crankshaft end thrust is taken by split thrust washers located on both sides of rear main bearing. If main bearings will be reused, keep inserts with their respective caps so they can be reinstalled in their original positions.

Crankshaft standard main journal diameter is 69.81-69.83 mm (2.7485-2.7492 inches) with a wear limit of 69.77 mm (2.7470 inches). Desired main bearing clearance is 0.04-0.10 mm (0.0016-0.0040 inch).

Crankpin standard diameter is 57.11-57.13 mm (2.2485-2.2492 inches) with a wear limit of 57.07 mm (2.2470 inches). Desired rod bearing running clearance is 0.06-0.10 mm (0,0024-0.0040 inch).

Main bearings and connecting rod bearings are available in 0.25, 0.51 and 0.76 mm (0.010, 0.020 and 0.030 inch) undersizes. The crankshaft is hardened by the Tufftride process and must be rehardened after regrinding. If facilities are not available for Tufftriding, crankshaft should be renewed.

Crankshaft end play should be 0.05-0.38 mm (0.002-0.015 inch). Standard thrust washer thickness when new is 3.07-3.12 mm (0.121-0.123 inch). Oversize thrust washers are available which have a thickness of 3.26-3.31 mm (0.1285-0.1305 inch). When installing thrust washers, be sure steel side of thrust washers is against main bearing housing.

To reinstall crankshaft and bearings, reverse the removal procedure. Note that main bearing caps are numbered and also marked with a serial number (Fig. PR1-21). When correctly installed, serial number on cap should be on same side as serial number stamped on bottom of cylinder block. Tighten bearing cap mounting screws to 150 N·m (110 ft.-lbs.).

REAR OIL SEAL

ROPE TYPE SEAL. A rope type crankshaft rear oil seal is used on some 3.152 and D3.152 engines. The rope seal fits into grooves of two-piece retainer which bolts around crankshaft flange. The rope type seal is precision cut to length and must be installed in retainer halves so 0.25-0.50 mm (0.010-0.020 inch) of the seal projects from each end of the retainer halves. Use a round bar to roll seal into grooves to compress the seal. Lubricate the exposed surface of seal with graphite grease. Apply sealing compound to gasket surfaces, then install retainer halves. Make sure retainer with oil shroud is towards top of engine. Tighten retainer clamp bolts to initial torque of 8 N·m (6 ft.-lbs.), then tighten seal retainer mounting screws to 16 N·m (12 ft.-lbs.). Finally, tighten clamp bolts to final torque of 16 N·m (12 ft.-lbs.).

LIP TYPE SEAL. A spring loaded, lip type crankshaft rear oil seal is used on most engines. An early style seal had a flat face as shown in Fig. PR1-22 while later style seal has a dust seal lip protruding rearward as shown in Fig. PR1.23.

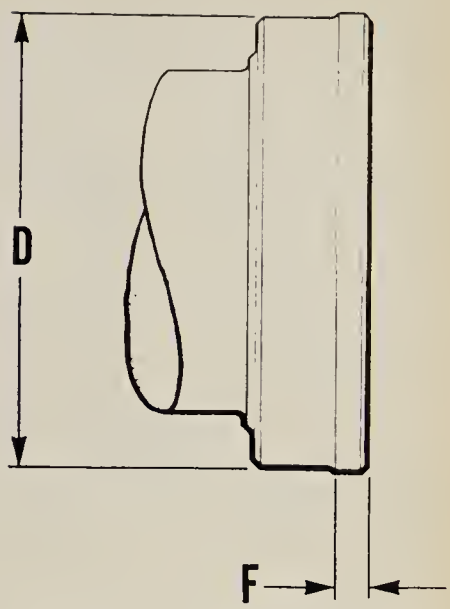


Fig. PR1-24—Oil seal contact area of crankshaft rear flange may be remachined to a minimum diameter (D) of 133.17 mm (5.243 inches). However, original diameter must be maintained for distance (F) of 4.8 mm (3/16 inch) from rear face of flange.

On original production engines, early style seal is installed flush with rear face of retainer and late style seal is installed deeper into housing as shown at A – Fig. PR1-23. When installing a new seal on a worn crankshaft, seal may be pressed further inward (position "B" or "C" – Fig. PR1-22 or PR1-23) to obtain an unworn seal contact point on crankshaft flange.

If all three seal positions have been used, the crankshaft flange may be remachined undersize to a minimum diameter (D – Fig. PR1-24) of 133.17 mm (5.243 inches). However, original diameter must be maintained for distance (F) of 4.8 mm (3/16 inch) from rear face of crankshaft flange for flywheel mounting. When crankshaft flange has been reground, new seal should be installed in original production location.

Be sure to lubricate crankshaft flange and oil seal lip with engine oil prior to reassembly. Using suitable tools, install seal assembly being careful to protect lip of seal.

PERKINS

Model	No. Cyls.	Bore	Stroke	Displ.
4.99	4	76.2 mm (3.0 in.)	88.9 mm (3.5 in.)	1620 cc (98.9 cu. in.)
4.107	4	79.4 mm (3.125 in.)	88.9 mm (3.5 in.)	1760 cc (107.4 cu. in.)
4.108	4	79.4 mm (3.125 in.)	88.9 mm (3.5 in.)	1760 cc (107.4 cu. in.)
4.154	4	88.9 mm (3.5 in.)	101.6 mm (4.0 in.)	2520 cc (154 cu. in.)

All engines in this section are liquid-cooled, four-stroke, indirect injection diesels with vertical, inline cylinders. Crankshaft rotation is clockwise viewed from front. Firing order is 1-3-4-2. The engine identification number is stamped on the cylinder block behind the injection pump.

MAINTENANCE

LUBRICATION

Recommended crankcase oil is SAE 10W for temperatures from minus 18°C (0°F) to minus 1°C (30°F), SAE 20W for temperatures between minus 1°C (30°F) and 27°C (80°F) or SAE 30 for temperatures above 27°C (80°F). Use of multiviscosity oils is also acceptable. Oil must meet MIL-L-46152 or MIL-L2104C specifications. However, if engine is new or just overhauled, manufacturer does not recommend using MIL-L-2104C specification oil until after the first oil change.

Engine oil and filter element should be renewed after every 150 hours of operation or every 3 months, whichever occurs first. Crankcase capacity varies according to application.

COOLING SYSTEM

Manufacturer recommends using a mixture of water and ethylene glycol antifreeze in the cooling system. In addition to providing protection against freezing, the antifreeze solution contains additives to protect against corrosion and also raises the boiling point of the coolant. If an antifreeze solution is not used, an approved corrosion inhibitor should be added to the water.

FUEL SYSTEM

FUEL FILTER AND BLEEDING. The paper element type fuel filter should be renewed after every 450 hours of operation or once a year, whichever comes first. However, if engine indicates signs of fuel starvation, filter should be renewed regardless of hours of operation.

Whenever fuel filter has been renewed or fuel lines have been disconnected, air must be bled from the fuel system as follows: loosen the vent screws on top of fuel filter housing, the hydraulic head locking screw (B – Fig. PR2-1) on side of pump body and the vent screw (A) on top of governor housing. Manually actuate fuel lift pump priming lever until air-free fuel flows from each vent screw.

NOTE: If fuel lift pump priming lever cannot be moved, fuel pump is at maximum lift position on camshaft lobe. Turn crankshaft one revolution to reposition camshaft.

Retighten vent screws in the following order: Filter vent screw, head locking screw and governor vent screw. Then loosen fitting at injection pump fuel inlet (F). Operate hand primer until fuel flows from around the threads, then retighten fitting. Loosen high pressure fuel line fittings at the injectors. With stop control in "run" position and throttle at full speed position, crank engine with starter motor until fuel is discharged from the fuel pipes. Retighten fittings and start engine.

ENGINE ADJUSTMENT SPEED. The engine should be at normal operating temperature when checking and adjusting engine speeds. Low idle speed is adjusted using screw (6 – Fig. PR2-1). Speed should be adjusted in conjunction with setting the antistall device. Recommended low idle speed may vary depending on engine application.

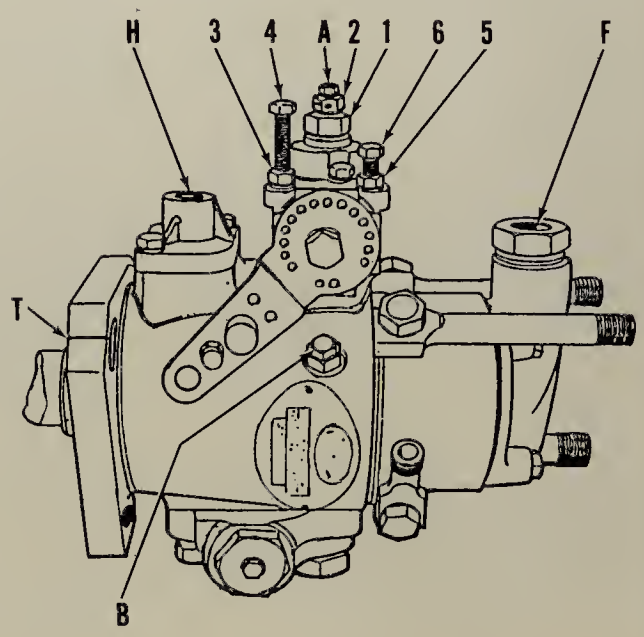


Fig. PR2-1—Illustration of typical C.A.V. injection pump equipped with hydraulic governor and antistall device.

A. Governor housing bleed screw
B. Pump body bleed screw
F. Fuel inlet fitting
H. Timing inspection cover & fuel return fitting
T. Timing scribe mark
1. Locknut
2. Antistall device adjusting screw
3. Locknut
4. High speed adjusting screw
5. Locknut
6. Idle speed adjusting screw

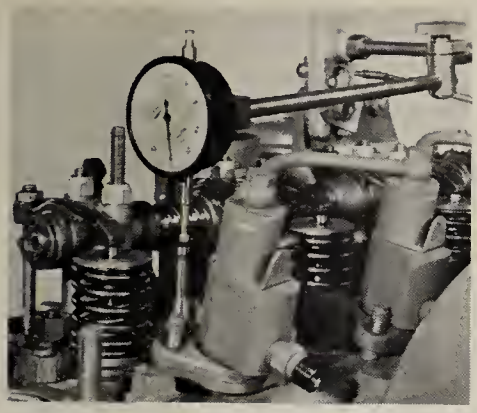


Fig. PR2-2—Remove valve spring from either valve stem on number 1 cylinder and install a dial indicator on end of valve stem as shown to find piston TDC. Set injection pump timing as outlined in text.

To adjust, loosen antistall screw (2) two complete turns. Adjust idle speed screw (6) until specified speed is obtained. Turn antistall screw in until there is a slight increase in speed, then turn screw back out ½ turn and tighten locknut (1). To check adjustment, accelerate to maximum speed, then return control lever to idle position and note time required for speed to return to idle. If return time exceeds three seconds, the device is screwed in too far. If engine should stall, the device has been screwed out too far. Readjust if necessary.

The maximum no-load speed adjusting screw (4) is sealed at the factory and should not be altered while engine is under warranty without factory authority. The maximum no-load speed setting will vary according to engine application. The specified speed setting can be determined from the injection pump setting code stamped on the pump name plate. The last four numbers of the code indicate the maximum no-load speed. A typical setting code is EH39/1200/0/4480 with 4480 being the specified maximum speed setting. Adjust maximum speed screw (4) as necessary to obtain recommended speed. Do not exceed specified speed. Install a seal wire after completing adjustment to secure adjustment.

INJECTION PUMP TIMING. If engine timing gears are correctly installed and timed and scribed line (T–Fig. PR2-1) on pump mounting flange is aligned with scribed line on rear of timing gear housing (pump with mechanical governor) or scribed line on flange of pump mounting adapter housing (pump with hydraulic governor), injection timing should be correct. Scribe lines may be aligned by loosening pump mounting nuts and shifting pump in slotted mounting holes.

To check pump internal timing marks, the fuel return adapter plate (pump with hydraulic governor) or inspection cover (pump with mechanincal governor) must be removed. The pump rotor is marked with a number of scribed lines, each one identified with a letter. A snap ring, with one end having a square edge, is also located inside the pump housing. When the appropriate scribed line is aligned with square edge of snap ring, beginning of injection for number 1 cylinder should occur. Refer to Fig. PR2-3.

Fig. PR2-3—Align proper timing line (A or C) on injection pump rotor with square end of snap ring when number 1 piston is at specified static timing position. Refer to text.

NOTE: On early pumps, the snap ring had a line scribed on one end for timing purposes.

If correct setting of snap ring is in doubt, the pump must be removed to check and adjust snap ring position. Connect an injector test pump to number 1 outlet fitting of injection pump, then actuate test pump to obtain a pressure of 9750 kPa (440 psi). Rotate injection pump shaft by hand until it locks up. At this point, adjust snap ring position so square edge is aligned with scribed line (Fig. PR2-3) marked with letter "A" (pump with hydraulic governor) or letter "C" (pump with mechanical governor). Reinstall pump.

To check pump to engine timing, proceed as follows: Remove valve cover, then rotate crankshaft until number 1 piston is at TDC on compression stroke. At TDC position, number 4 cylinder exhaust valve should be open and timing pin in front cover should engage hole in rear of crankshaft pulley. Remove valve spring from one of the valves on number 1 cylinder and allow valve to rest on top of piston.

NOTE: Install a piece of wire or rubber band around the valve stem to prevent valve from accidentally falling into cylinder.

Position a dial indicator against end of valve stem and zero indicator gage at piston TDC (Fig. PR2-2). Turn crankshaft in opposite direction of normal rotation (clockwise viewed from front) until gage indicates specified BTDC position as listed in the following table. The correct timing figures can be found by reference to the prefix letters and numbers of the setting code on the injection pump name plate.

Prefix Code	Static Timing (BTDC)	Piston Position (BTDC)
4.99 Engine		
AH28, BH26	26°	5.74 mm (0.226 in.)
CH35	19°	3.05 mm (0.120 in.)
DH19	26°	5.74 mm (0.226 in.)
LH20, LH26	20°	3.40 mm (0.134 in.)
LH29	22°	4.06 mm (0.160 in.)
MH26	18°	2.75 mm (0.108 in.)
4.107 Engine		
CH35	19°	3.05 mm (0.120 in.)
LH23, LH28, LH29, LH31	20°	3.40 mm (0.134 in.)
LH31/900/2/2770, LH31/900/2/3130, LH31/900/9/1880	22°	4.06 mm (0.160 in.)
MH27	18°	2.75 mm (0.108 in.)
PH28, PH30	18°	2.75 mm (0.108 in.)
PH34	20°	3.40 mm (0.134 in.)
4.108 Engine		
EH34E, EH39	18°	2.75 mm (0.108 in.)
LH30	22°	4.06 mm (0.160 in.)
PH23E, PH25E	18°	2.75 mm (0.108 mm)
PH25E/500/9/2090	21°	3.73 mm (0.147 in.)
PH27, PH30	18°	2.75 mm (0.108 in.)
PH30/500/5/2450, PH30/500/6/1570, PH30/500/9/1990, PH30/500/9/2090	21°	3.73 mm (0.147 in.)
RH30E, SH33E	21°	3.73 mm (0.147 in.)
TH23E	20°	3.40 mm (0.134 in.)

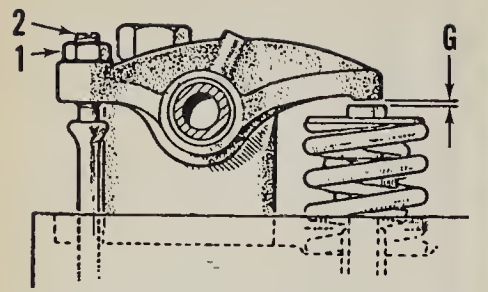


Fig. PR2-4—Loosen locknut (1) and turn adjusting screw (2) until recommended valve clearance (G) is obtained.

With piston at specified BTDC position, appropriate scribed line ("A" for pump with hydraulic governor or "C" for pump with mechanical governor) should be aligned with square edge of snap ring. If timing mark is not aligned, loosen pump mounting nuts and move pump in slotted mounting holes until mark is aligned. If timing mark cannot be aligned by shifting pump on mounting studs, timing gear front cover should be removed and gear timing checked.

REPAIRS

TIGHTENING TORQUES

Refer to the following table for special tightening torques. Fastener threads should be lightly oiled before assembly. Whenever self-locking nuts are removed, they must be renewed.

Models 4.99 and 4.107

Connecting rod	57 N·m (42 ft.-lbs.)
Crankshaft pulley	203 N·m (150 ft.-lbs.)
Cylinder head	57 N·m (42 ft.-lbs.)
Flywheel	81 N·m (60 ft.-lbs.)
Idler gear	49 N·m (36 ft.-lbs.)
Injector	16 N·m (12 ft.-lbs.)
Main bearing caps	57 N·m (42 ft.-lbs.)

Model 4.108

Connecting rod	57 N·m (42 ft.-lbs.)
Crankshaft pulley	Refer to text.
Cylinder head	81 N·m (60 ft.-lbs.)
Flywheel	81 N·m (60 ft.-lbs.)
Idler gear	49 N·m (36 ft.-lbs.)
Injector	16 N·m (12 ft.-lbs.)
Main bearing caps	115 N·m (85 ft.-lbs.)

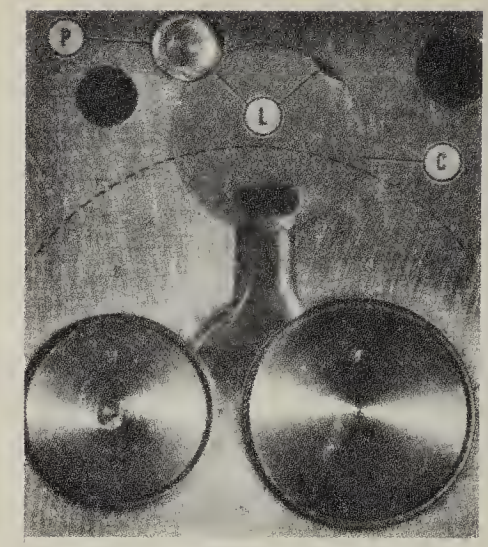


Fig. PR2-5—View of cylinder head showing installed combustion chamber cap (C). Broken line indicates approximate location of cylinder wall when head is installed.

C. Combustion chamber cap
L. Locating slots
P. Expansion plug

Model 4.154

Camshaft gear	68 N·m (50 ft.-lbs.)
Connecting rod:	
Plain nuts	61 N·m (45 ft.-lbs.)
Phosphated nuts	82 N·m (60 ft.-lbs.)
Crankshaft pulley	166 N·m (123 ft.-lbs.)
Cylinder head	115 N·m (85 ft.-lbs.)
Flywheel	108 N·m (80 ft.-lbs.)
Idler gear	28 N·m (21 ft.-lbs.)
Injector	16 N·m (12 ft.-lbs.)
Main bearing caps	115 N·m (85 ft.-lbs.)

VALVE ADJUSTMENT

Clearance between rocker arms and valve stems should be checked and adjusted with engine cold. Recommended clearance for both intake and exhaust valves is 0.30 mm (0.012 inch). Adjust valves in the following sequence by loosening locknut (1–Fig. PR2-4) and turning adjusting screw (2) until correct size feeler gage can be inserted at (G). Recheck clearance after tightening locknut.

Be sure fuel pump control is in "stop" position. Rotate crankshaft in normal direction until valves on number 4 cylinder are in "overlap" position (intake opening and exhaust closing), then adjust valves of number 1 cylinder. Similarly, with valves of number 2 cylinder in overlap, adjust valves of number 3 cylinder. With valves of number 1 cylinder in overlap, adjust valve clearance on number 4 cylinder. With valves of number 3 cylinder in overlap, adjust valves of number 2 cylinder.

CYLINDER HEAD

To remove cylinder head, first drain cooling system and disconnect hose at water outlet. Remove valve cover. Disconnect starting aid fuel line and electrical wire. Disconnect fuel lines and plug all openings. Remove injectors. Remove intake and exhaust pipes. Loosen cylinder head screws in opposite order of tightening sequence shown in Fig. PR2-6 or PR2-7. Remove rocker arms and shaft assembly and push rods, then lift off cylinder head.

Clean cylinder head and inspect for wear and other damage. Check cylinder head distortion using a straightedge and feeler gage. Maximum allowable distortion measured crosswise is 0.08 mm (0.003 inch) concave and 0.13 mm (0.005

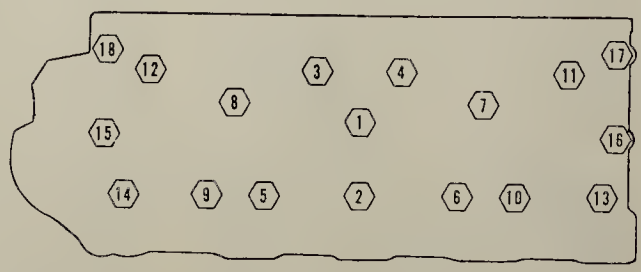


Fig. PR2-6—On 4.99, 4.107 and 4.108 engines, follow sequence shown when tightening cylinder head nuts. Refer to text for tightening procedure.

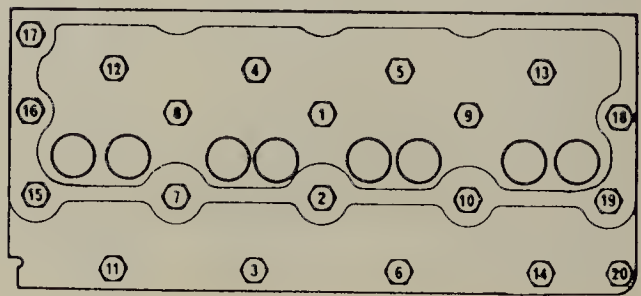


Fig. PR2-7—On 4.154 engines, follow sequence shown when tightening cylinder head cap screws. Refer to text.

inch) convex. Maximum allowable distortion measured lengthwise is 0.15 mm (0.006 inch). Remachining of cylinder head surface is not permitted.

Precombustion chamber caps (C – Fig. PR2-5) are retained in cylinder head by expansion plug (P). To remove combustion chamber cap, insert a brass drift through injector bore and tap out cap and expansion plug. When installing cap, align opening with machined channel in cylinder head and secure the cap by installing a new expansion plug. Height of insert in relation to cylinder head surface must be 0.051 mm (0.002 inch) above to 0.051 mm (0.002 inch) below on 4.99, 4.107 and 4.108 engines or 0.02 mm (0.001 inch) above to 0.07 mm (0.003 inch) below on 4.154 engine.

Model 4.99 and 4.107 engines use either a copper and asbestos or a copper, steel and asbestos cylinder head gasket. These gaskets should be installed using a light coating of sealing compound on both sides. Both types of gaskets are marked "TOP FRONT" to indicate correct installation position.

Model 4.108 engine uses a "Klinger" type cylinder head gasket which is made of black composite material. Do not use gasket sealing compound with this type gasket. It must be installed dry. It is very important that gasket is positioned correctly on cylinder block with the words "TOP FRONT" properly located, otherwise the steel beading will be pinched between cylinder head and top of cylinder liners.

On 4.154 engines, cylinder head gasket must be installed dry. Do not use gasket sealing compound.

To reinstall cylinder head on 4.99, 4.107 and 4.108 engines, proceed as follows: Position cylinder head and gasket onto cylinder block. Lubricate threads of stud nuts with engine oil. Tighten nuts following sequence shown in Fig. PR2-6 progressively in three steps to a final torque of 57 N·m (42 ft.-lbs.) for 4.99 and 4.107 engines or 81 N·m (60 ft.-lbs.) for 4.108 engine. Final tightening sequence should be repeated to be sure all nuts are properly tightened. Install push rods and rocker arm assembly. Tighten rocker shaft oil feed line finger tight at this time. Tighten rocker bracket mounting nuts evenly to 20 N·m (15 ft.-lbs.), then tighten oil feed line fitting securely. Complete installation and run engine until it reaches operating temperature. Retighten cylinder head nuts in recommended sequence to specified torque. If a nut does not move before specified torque is reached, loosen nut about ⅓ turn, then retighten to specified torque. After retightening all nuts, recheck the first 10 nuts in sequence to ensure correct torque. Do not loosen nuts during this final check. After engine cools, readjust valve clearance as previously outlined. Manufacturer also recommends that cylinder head nuts be retorqued again between 25 to 50 hours of engine operation.

On 4.154 engine, install cylinder head, push rods and rocker shaft assembly. Be sure notch in shaft is positioned on front mounting stud and oil passage in front rocker support is aligned with oil passage in cylinder head. Install cylinder head mounting screws and tighten progressively in three steps following sequence shown in Fig. PR2-7. Final torque should be 115 N·m (85 ft.-lbs). Repeat final torque tightening step to ensure all cap screws are correctly tightened. Complete installation and run engine until normal operating temperature is reached. Retorque cylinder head cap screws (while hot) following recommended tightening sequence. Manufacturer recommends that cylinder head cap screws be retorqued again after 20 to 40 hours of engine operation.

VALVE SYSTEM

On early engines, valves are numbered and the cylinder head has corresponding numbers to ensure correct assembly. On later engines, the valves are not numbered. If valves are to be reused, they should be suitably identified so they can be reinstalled in original positions.

Valve face and seat angles are 45° for both intake and exhaust. The valves seat directly in the cylinder head making it important that a minimum amount of material be removed when machining valve seats. Valve recession (depth valve head is below surface of cylinder head) should be measured to determine condition of cylinder head and valves. Specified valve recession for 4.99, 4.107 and 4.108 engines is 0.711-0.991 mm (0.028-0.039 inch) for intake and 0.533-0.813 mm (0.021-0.032 inch) for exhaust. Maximum allowable recession is 1.22 mm (0.048 inch) for both valves. On 4.154 engine, specified valve recession is 0.74-1.04 mm (0.029-0.041 inch) for intake and 0.69-1.02 mm (0.027-0.040 inch) for exhaust. Maximum allowable recession is 1.52 mm (0.060 inch) for both valves.

Valve seat inserts are available for installation on 4.99, 4.107 and 4.108 engines to correct excessive valve recession. Before installing valve seat inserts, the valve guides must first be renewed to provide an accurate pilot bore for machining operations required to fit inserts. After inserts are installed, grind valve seats as required to obtain minimum limit of specified valve recession.

All engines are equipped with renewable valve guides. On 4.154 engine, inside diameter of guides should be 7.99-8.01 mm (0.3145-0.3155 inch). Valve stem diameter is 7.92-7.95 mm (0.312-0.313 inch) for intake and exhaust. Desired clearance of valve stem in guide is 0.04-0.09 mm (0.0015-0.0035 inch). Maximum allowable clearance is 0.13 mm (0.005 inch) for intake and 0.15 mm (0.006 inch) for exhaust. On 4.99, 4.107 and 4.108 engines, valve guide inner diameter should be 7.978-8.014 mm (0.3141-0.3155 inch). Valve stem diameter is 7.925-7.950 mm (0.312-0.313 inch) for intake valve and 7.912-7.937 mm (0.3115-0.3125 inch) for exhaust. Desired clearance of valve stem in guide is 0.028-0.089 mm (0.0011-0.0035 inch) for intake and 0.041-0.102 mm (0.0016-0.004 inch) for exhaust. Maximum allowable clearance is 0.13 mm (0.005 inch) for intake and 0.15 mm (0.006 inch) for exhaust.

Valve guides are an interference fit in cylinder head. When renewing guides, use suitable tools to remove and install guides to prevent damage to guides or cylinder head. Guides should be pressed in from the top until top of guide protrudes 20.32-20.70 mm (0.800-0.815 inch) above surface of cylinder head on 4.99, 4.107 and 4.108 engines. Guides should protrude 16.20-16.81 mm (0.638-0.662 inch) on 4.154 engine.

Some engines use inner and outer valve springs. Manufacturer advises that new valve springs be installed at time of a major engine overhaul. Inspect springs for distortion or other damage. Springs must meet the following values:

Models 4.99, 4.107 and 4.108

Outer spring	
Test length	42.51 mm (1.780 in.)
Load at test length	24.13-26.67 kg (53.2-58.8 lbs.)
Inner spring (if used)	
test length	38.86 mm (1.530 in.)
Load at test length	1.21-13.9 kg (26.6-30.6 lbs.)

Model 4.154

Outer spring	
Test length	40.38 mm (1.59 in.)
Load at test length	17.2-19.0 kg (38-42 lbs.)
Inner spring	
Test length	37.84 mm (1.49 in.)
Load at test length	12.05-13.35 kg (26.6-29.4 lbs.)

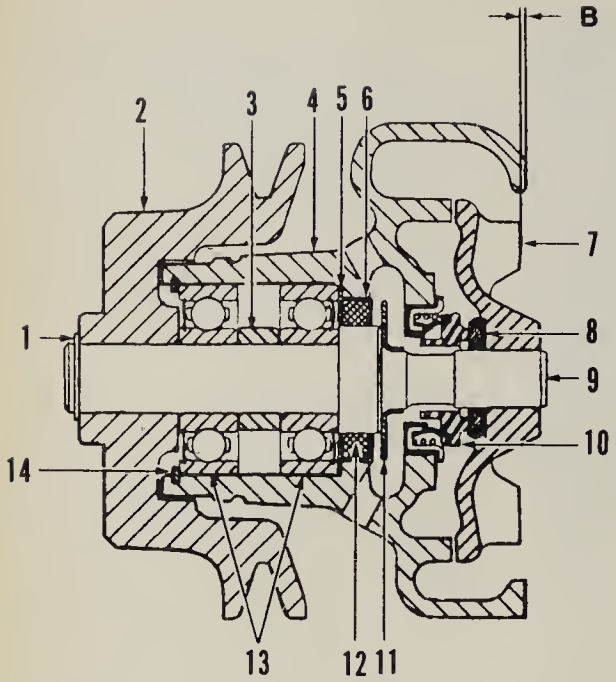


Fig. PR2-8—Cross section view of separate bearing type water pump used on some 4.99, 4.107 and 4.108 engines. Dimension (B) should be 0.00-0.15 mm (0.000-0.006 inch).

1. Snap ring
2. Pulley
3. Spacer
4. Housing
5. Retainer flange
6. Seal retainer
7. Impeller
8. Counterface
9. Shaft
10. Seal assy.
11. Thrower
12. Felt seal
13. Bearings
14. Snap ring

Inspect rocker arms and shaft for excessive wear and other damage. Be sure to identify parts in order of removal so they can be reinstalled in their original positions. On 4.99, 4.107 and 4.108 engines, rocker shaft diameter is 15.805-15.843 mm (0.6223-0.6237 inch) and rocker arm bushing inner diameter should be 15.862-15.894 mm (0.6223-0.6237 inch). Recommended operating clearance of rocker shaft in bushing is 0.019-0.089 mm (0.0008-0.0035 inch) with a wear limit of 0.13 mm (0.005 inch). On 4.154 engine, rocker shaft outer diameter is 15.83-15.86 mm (0.6234-0.6244 inch) and rocker arm bushing inner diameter is 15.87-15.89 mm (0.625-0.6258 inch). Recommended operating clearance of shaft in bushing is 0.01-0.06 mm (0.0006-0.0024 inch) with a wear limit of 0.13 mm (0.005 inch). Rocker arm bushings are renewable. When installing new bushings, be sure oil hole in bushing is aligned with oil hole in rocker arm. On late 4.154 engines, replacement bushing is supplied without an oil hole. The bushing must be drilled, after installation, with a 2 mm (5/64 inch) drill through the rocker arm oil hole.

COOLING SYSTEM

The engine coolant is circulated by a centrifugal type pump which is belt driven from the crankshaft pulley. Belt tension should be adjusted so belt deflects about 10 mm (3/8 inch) when depressed with moderate thumb pressure. After renewing drive belt, it is recommended that belt tension be rechecked after the first two hours of operation to allow for initial stretch of a new belt.

A thermostat is located in the cylinder head water outlet. The thermostat should start to open at 79.5°-83.5°C (175°-182°F) and be fully open at about 96°C (205°F).

Models 4.99, 4.107 and 4.108

Two different types of water pumps are used. In one type of pump, the impeller shaft is supported by two separate bearings (Fig. PR2-8), and in the other type of pump, the shaft and bearings are a combined assembly (Fig. PR2-9).

WATER PUMP (SEPARATE BEARING TYPE). To disassemble pump, first remove pulley (2-Fig PR2-8). Press shaft (9) rearward out of bearings (13), then press impeller (7) off shaft and remove seal assembly. Remove retaining ring (14) and press bearings forward out of pump housing.

To reassemble pump, position thrower (11) in pump body. Install seal retainer (6), felt seal (12) and retaining flange (5) with dish of flange towards the seal. Press bearings and spacer onto impeller shaft with shielded side of bearings facing outward towards front and rear ends of shaft. Lubricate inner surfaces of bearings with high melting point grease, then press the bearings and shaft assembly into the pump housing and install retaining ring (14). Press

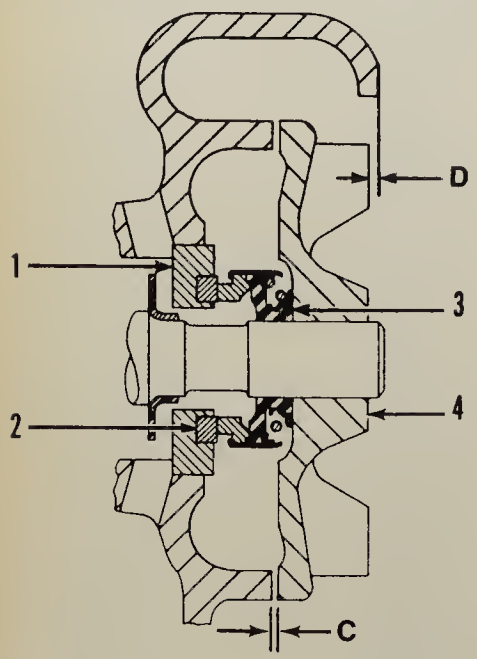


Fig. PR2-8A—View of seal assembly used on early style pumps. Some pumps did not use a counterface (2) in the insert (1). Refer to text for dimension (C) or (D).

1. Insert
2. Counterface
3. Seal assy.
4. Impeller

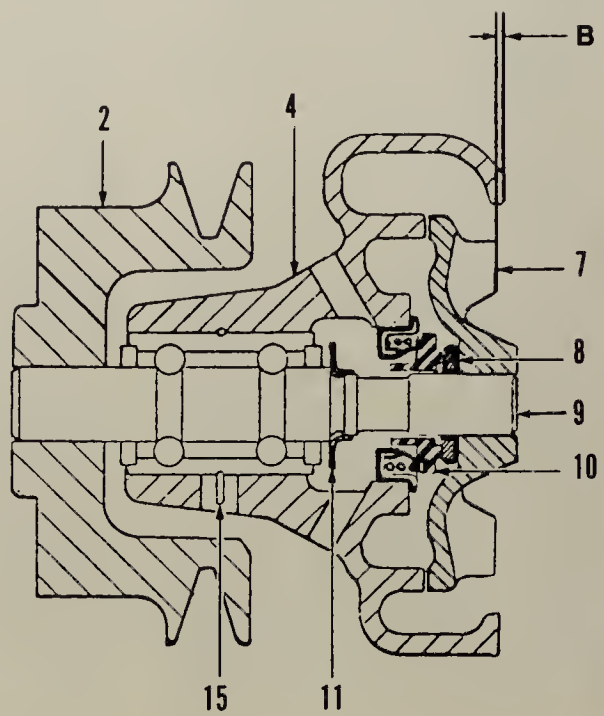


Fig. PR2-9—Cross section view of combined bearing and shaft style water pump assembly used on some 4.99, 4.107 and 4.108 engines. Dimension (B) should be 0.00-0.15 mm (0.000-0.006 inch).

2. Pulley
4. Housing
7. Impeller
8. Counterface
9. Shaft & bearing assy.
10. Seal assy.
11. Thrower
15. Clip

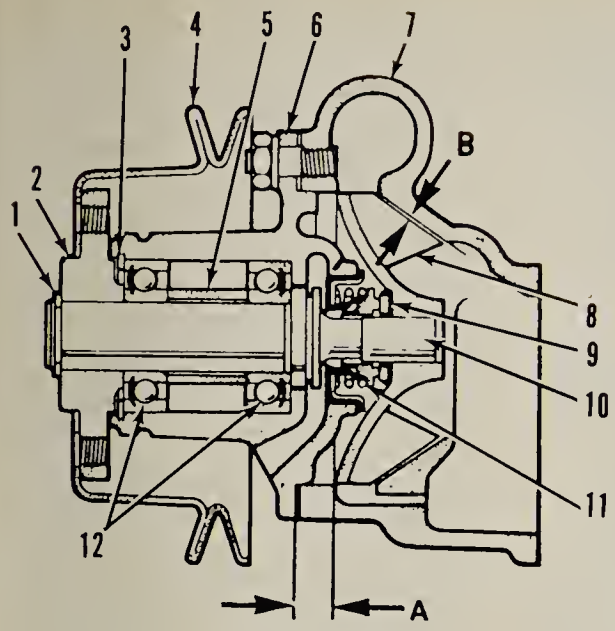


Fig. PR2-10—Cross section view of water pump with two-piece housing used on some 4.154 engines. Refer to text for dimensions (A) and (B).

1. Snap ring
2. Hub
3. Snap ring
4. Pulley
5. Spacer
6. Bearing housing
7. Impeller housing
8. Impeller
9. Counterface
10. Shaft
11. Seal assy.
12. Bearings

thrower onto the shaft. Install any pump mounting cap screws that cannot be installed after pulley is in position, then support end of shaft and press pulley on until it contacts front bearing. Reinstall seal assembly onto shaft. Refer to Fig. PR2-8 for assembled view of late style seal and PR2-8A for early style seal. Support front end of shaft, then press on impeller until rear face of impeller is 0.00-0.15 mm (0.000-0.006 inch) below rear face of body (B – Fig. PR2-8) on late style pump. On early style pump without a seal counterface (2 – Fig. PR2-8A), press impeller on until clearance (C) between front face of impeller and pump body is 0.12-0.25 mm (0.005-0.010 inch). On early style pump with a seal counterface (2), press impeller on until rear face of vanes is 0.74-0.84 mm (0.029-0.033 inch) below rear face of body (D).

WATER PUMP (COMBINED BEARING AND SHAFT TYPE). To disassemble pump, remove pulley (2 – Fig. PR2-9) using a suitable puller. Remove retainer clip (15) through opening in pump body. Press shaft and bearing assembly (9) rearward from pump body. Press shaft out of impeller (7) and remove seal assembly (10).

To reassemble pump, press bearings and shaft (with smaller diameter end rearward) into pump body until retaining clip (15) can be installed in bearing groove. Install any pump mounting cap screws that cannot be installed after pulley is in position, then support rear end of shaft and press pulley on until front of pulley is flush with end of shaft. Press thrower (11) onto shaft. Be sure carbon face of seal (10) and counterface (8) are clean, then assemble into pump housing. Support front end of shaft and press impeller onto shaft until rear face of vanes is 0.00-0.15 mm (0.000-0.006 inch) below rear face of pump body (B).

Model 4.154

WATER PUMP. Two different styles of water pumps have been used on this engine. One type of pump used a two-piece housing (Fig. PR2-10), while the other type of pump uses a one-piece housing (Fig. PR2-10A).

To disassemble either pump, remove retaining ring (1), then use a suitable puller to remove hub (2). Remove impeller housing (7 – Fig. PR2-10) on two-piece housing pumps. On both pumps, press shaft (10) complete with seal and impeller out through rear of housing. Remove snap ring (3), then press bearings (12) and spacer (5) out through front of housing. Press shaft out of impeller and remove seal assembly.

To reassemble, press bearings and spacer onto shaft with the shielded side of bearings facing outward towards front and rear ends of shaft. Pack inner surfaces of bearings into housing and install retaining ring (3). Support impeller end of shaft and press hub onto shaft. Install retaining ring (1). Install seal (11) and counterface (9) with ceramic face of counterface mating against carbon face of seal. Support front end of shaft, then press impeller onto shaft until rear face of impeller is 0.38-0.76 mm (0.015-0.030 inch) below rear surface of pump body (B – Fig. PR2-10A) on one-piece pump housings. On pumps with two-piece housings, press impeller onto shaft until clearance (A – Fig. PR2-10) between front of impeller and pump body is 9.90-10.49 mm (0.390-0.413 inch). Install impeller housing (7) and check running clearance (B) between impeller vanes and housing. Clearance should be 0.10-0.14 mm (0.004-0.045 inch). On either style pump, be sure pump shaft turns freely after assembly.

Reinstall pump assembly and tighten mounting cap screws to 20 N·m (15 ft.-lbs.).

INJECTOR

When removing injectors, it is of utmost importance to immediately plug all openings in fuel system to prevent entry of dirt. Be sure to remove copper seal washer from injector bore in cylinder head.

Before reinstalling injectors, be sure bore in cylinder head is clean. It is recommended that copper seal washers be renewed whenever injectors are

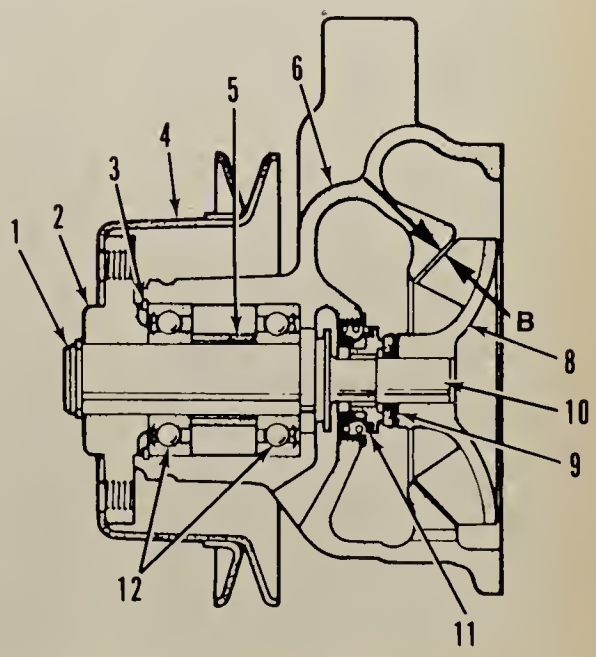


Fig. PR2-10A—Cross section view of water pump with one-piece housing used on some 4.154 engines. Refer to text for dimension (B). Refer to Fig. PR2-10 for parts identification.

removed. Tighten injector mounting nuts to 16 N·m (12 ft.-lbs.).

TESTING. A special nozzle test pump should be checked for specified opening pressure, nozzle leakage and correct spray pattern.

WARNING: Fuel leaves the injector nozzle with sufficient force to penetrate the skin. When testing, keep yourself clear of nozzle spray.

Connect injector to nozzle test pump, then operate tester lever several quick strokes to purge air from injector and to make sure nozzle valve is not stuck. Then operate tester lever slowly while noting nozzle opening pressure reading on tester gage. Specified opening pressure is 13680-15200 kPa (1980-2200 psi). Opening pressure is adjusted by removing cap nut, loosening locknut and turning adjusting screw until desired pressure is obtained.

To check nozzle valve for leakage, operate tester lever slowly to maintain pressure at 2000 kPa (300 psi) below opening pressure and observe nozzle tip for leakage. If a drop falls from nozzle tip within a 10 second period, nozzle valve is not seating and injector should be overhauled or renewed.

To check spray pattern, operate the tester lever several quick strokes (about one stroke per second). Spray should be uniform and well atomized and nozzle should produce a "chatter" sound when operting properly.

INJECTION PUMP

A D.P.A. type injection pump manufactured by C.V.A. is used on all engines. Some pumps are equipped with a hydraulic governor while other pumps use a mechanical flyweight type governor. It is recommended that the injection pump be tested and serviced only by a shop qualified in diesel fuel injection repair.

To remove injection pump, first clean pump and surrounding area. Disconnect and remove fuel lines from pump and immediately plug all openings. Disconnect speed control linkage and shut-off control. On mechanical governor pumps, remove inspection cover from timing gear cover and remove pump drive gear mounting cap screws. On all pumps, remove pump mounting nuts and withdraw pump assembly.

To reinstall pump, reverse the removal procedure. On hydraulic governor pumps, pump shaft has a master spline that mates with drive hub spline. On mechanincal governor pump, pump shaft has a dowel on the end which mates with slot in pump drive gear.

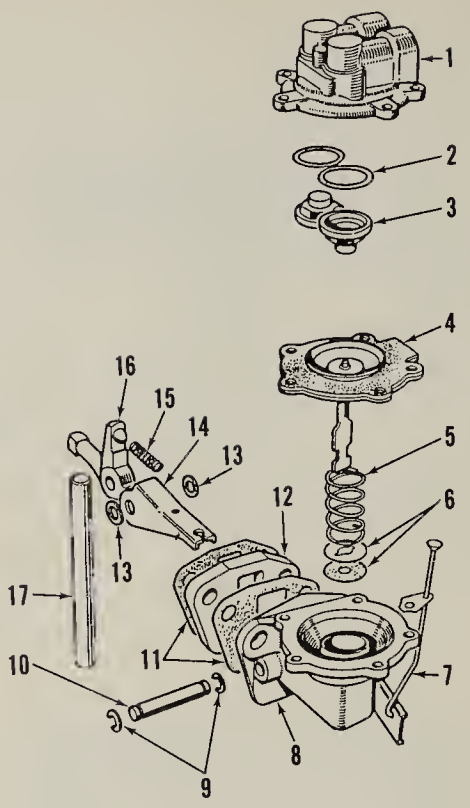


Fig. PR2-11—Exploded view of fuel lift pump. On early pumps, valves (3) were held in position by a clip and two screws (not shown).

1. Pump cover
2. "O" rings
3. Valves
4. Diaphragm
5. Spring
6. Spring retainer & gasket
7. Manual priming lever
8. Pump body
9. "C" clips
10. Pin
11. Gaskets
12. Spacer
13. Washers
14. Lever
15. Spring
16. Rocker
17. Push rod

Tighten drive gear mounting cap screws to 28 N·m (21 ft.-lbs.). Before tightening pump mounting nuts, align timing scribe marks on pump mounting flange (T – Fig. PR2-1). Bleed air from fuel system as outlined in MAINTENANCE section. If pump was renewed, check and adjust maximum no-load speed setting.

FUEL LIFT PUMP

The lift pump is a diaphragm type which is actuated by the engine camshaft. To check pump output, disconnect the fuel outlet line and install a 0-70 kPa (0-10 psi) pressure gage to pump outlet. Crank engine for 10 seconds and note gage pressure reading. If pressure is less than 25 kPa (3.75 psi), pump is defective. Also, note time required for pump pressure to drop to one half of reading obtained when engine was being cranked. If time is less than 30 seconds, pump is defective.

Service parts for pump repair are available separately. Refer to Fig. PR2-11 for an exploded view of fuel lift pump assembly. Inspect all parts for wear and damage and renew if necessary. Thoroughly clean both valve bores in cover (1) and install new valve gaskets (2). Insert a valve in the fuel inlet bore with its spring facing towards pump diaphragm. Install outlet valve in opposite direction. Press valves into cover using a piece of soft tubing having an ID of 9/16 inch and an OD of ¾ inch. Stake valves into cover in six places, between original stake marks, around each valve. Note that early pump valves are held in position by a retaining plate and two screws. Do not attempt to stake these valves into place. Install pump rocker arm and lever assembly into body in opposite order of removal being sure to properly locate lever washers (13) between outside of lever (14) and body (8). Install rubber seal and steel spring seat (6) and diaphragm return spring (5) into body. Install diaphragm (4) so flat of diaphragm pull rod aligns with lever (14). Push diaphragm down slightly and rotate it 90 degrees in either direction to engage lever. Install cover (1) on body (8), lining up scribe marks, and secure into position.

Install pump onto engine in opposite order of removal and reconnect fuel lines. Bleed fuel system as previously outlined.

PISTON, PISTON PIN AND RINGS

The pistons can be removed from the top after removing cylinder head, oil pan and connecting rod caps. Be sure to remove ring ridge or carbon deposits from top of cylinder before attempting to remove pistons. Before disassembling pistons from connecting rods, mark piston crown to indicate "front" in relation to "FRONT" marking cast on connecting rod. Also, number pistons to coincide with cylinder numbers so they can be reinstalled in original positions if reused. Keep pistons and connecting rods together as assemblies for proper reassembly.

Full floating piston pins are retained in pistons by two snap rings. Heating piston to 40°-50°C (100°-120°F) will ease removal and installation if pin is tight. Piston pin diameter is 22.225-22.23 mm (0.8750-0.8752 inch) for early 4.99 engines, 23.812-23.817 mm (0.09375-0.09377 inch) for late 4.99 and all 4.107 engines, 26.987-26.993 mm (1.0625-1.0627 inches) for 4.108 engines and 31.74-31.75 mm (1.2498-1.2499 inches) for 4.154 engines. Pin is a transition fit in piston bore. Inside diameter of piston bore should be 22.22-22.23 mm (0.8748-0.87525 inch) for early 4.99 engines, 23.81-23.82 mm (0.9374-0.9378 inch) for late 4.99 and all 4.107 engines, 26.989-26.994 mm (1.06255-1.06275 inches) for 4.108 engine with standard pistons, 26.992-26.996 mm (1.0627-1.0629 inches) for 4.108 engine

with controlled expansion pistons and 31.74-31.75 mm (1.2495-1.250 inches) for 4.154 engines.

Piston ring end gap is measured with ring positioned squarely in cylinder bore. Refer to the following table for specified end gap values.

Models 4.99 and 4.107

Compression and oil control rings.....0.30-0.43 mm (0.012-0.017 in.)

Model 4.108

Standard piston:
Compression and oil control ring.....0.23-0.43 mm (0.009-0.017 in.)
Controlled expansion piston (three ring):
Top ring.....0.31-0.59 mm (0.012-0.023 in.)
Second ring.....0.23-0.51 mm (0.009-0.020 in.)
Oil control ring.....0.31-0.59 mm (0.012-0.023 in.)
Controlled expansion piston (four ring):
Top ring.....0.30-0.58 mm (0.012-0.023 in.)
Second and third rings .....0.23-0.50 mm (0.009-0.020 in.)
Oil control ring.....0.25-0.53 mm (0.010-0.021 in.)

Model 4.154

Top ring .....0.36-0.69 mm (0.014-0.027 in.)
Second and third rings...0.28-0.61 mm (0.011-0.024 in.)
Fourth ring.....0.36-0.69 mm (0.014-0.027 in.)
Fifth ring.....0.28-0.61 mm (0.011-0.024 in.)

Inspect piston for wear and other damage. Renew piston if scoring is evident on piston skirt. Clean and inspect piston ring grooves for wear. Refer to the following table for specified ring width and ring side clearance values.

Models 4.99 and 4.107

Ring groove width:
Top.....2.034-2.06 mm (0.0801-0.0811 in.)
Second and third....1.638-1.664 mm (0.0645-0.0655 in.)
Fourth and fifth.....4.826-4.851 mm (0.190-0.191 in.)
Ring side clearance in groove:
Compression rings...0.051-0.102 mm (0.002-0.004 in.)
Oil control rings.....0.064-0.114 mm (0.0025-0.0045 in.)

Model 4.108

Standard piston:
Ring groove width–
Top.....2.045-2.070 mm (0.0805-0.0815 in.)
Second and third...1.638-1.664 mm (0.0645-0.0655 in.)
Fourth.....3.200-3.225 mm (0.126-0.127 in.)
Fifth.....4.826-4.851 mm (0.190-0.191 in.)
Ring side clearance in groove–
Top.....0.061-0.112 mm (0.0024-0.0044 in.)
Second and third...0.051-0.102 mm (0.002-0.004 in.)
Fifth.....0.063-0.114 mm (0.0025-0.0045 in.)

Model 4.108

Controlled Expansion Piston (Three Rings):
Ring groove width–
Top.....2.035-2.086 mm (0.080-0.082 in.)
Second.....2.53-2.55 mm (0.099-0.1005 in.)
Third.....4.80-4.826 mm (0.1890-0.1900 in.)
Ring side clearance in groove–
Top.....0.063-0.140 mm (0.0025-0.0055 in.)
Second.....0.039-0.089 mm (0.0015-0.0035 in.)
Third.....0.039-0.089 mm (0.0015-0.0035 in.)
Controlled Expansion Piston (Four Rings):
Ring groove width–
Top.....2.035-2.086 mm (0.0801-0.0821 in.)
Second and third.....1.64-1.65 mm (0.064-0.065 in.)
Fourth.....4.79-4.81 mm (0.1887-0.1895 in.)
Ring side clearance in groove–
Top.....0.05-0.13 mm (0.002-0.005 in.)
Second and third.....0.04-0.09 mm (0.0015-0.0035 in.)
Fourth.....0.05-0.09 mm (0.0020-0.0035 in.)

Model 4.154

Ring groove width:
Top, second and third.....2.44-2.46 mm (0.096-0.097 in.)
Fourth and fifth.....4.81-4.84 mm (0.1895-0.1905 in.)
Ring side clearance in groove:
All rings.....0.05-0.10 mm (0.002-0.004 in.)

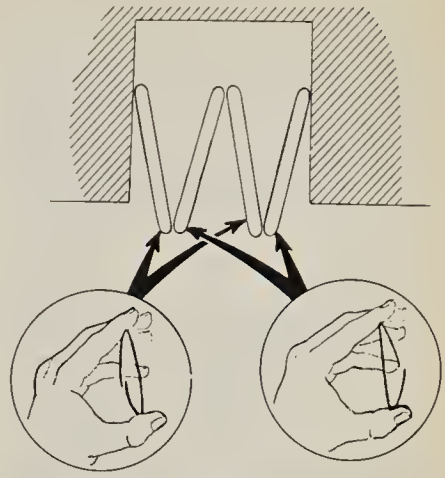


Fig. PR2-12—Install laminated oil scraper ring segments as shown. Ends of segments should point as shown when squeezed between thumb and finger.

Piston rings vary according to engine type and application. Be sure correct rings are used. Assemble rings on pistons in the following positions (reading from top of piston):

Models 4.99 and 4.107
1. Plain, parallel faced compression
2. Internally stepped compression
3. Internally stepped compression
4. Spring-loaded, chrome scraper
5. Slotted scraper

Model 4.108 (standard piston)
1. Plain, parallel face compression
2. Internally stepped compression
3. Internally stepped compression
4. Laminated segment oil control*
5. Slotted scraper

Model 4.108 (controlled expansion piston–three rings)
1. Chrome, taper face
2. Internally stepped taper face
3. Spring-loaded scraper

Model 4.108 (controlled expansion piston–four rings)
1. Chrome, parallel face compression
2. Internally stepped compression
3. Internally stepped compression
4. Spring-loaded scraper

Model 4.154
1. Chrome, parallel face compression
2. Internally stepped compression
3. Internally stepped compression
4. Chrome, slotted scraper
5. Slotted scraper

*Model 4.108 rated at 3000 rpm and below uses a slotted scraper oil ring in fourth groove.

One side of taper face and internally stepped (notched) compression rings should be marked "TOP" or "BTM" (bottom) to indicated correct assembly position. Be sure to install accordingly. The slotted scraper rings can be installed either side up. The laminated oil scraper ring must be assembled as shown in Fig. PR2-12. To assemble spring-loaded scra-

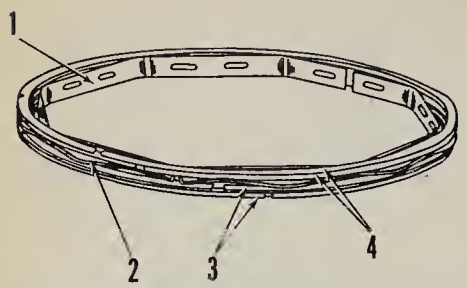


Fig. PR2-13—To assemble spring-loaded scraper ring, install internal expander (1), two bottom rail rings (3), spiral ring (2) and two top rail rings (4) in that order.

per rings, install internal expander (1—Fig. PR2-13) two bottom rail rings (3), spiral ring (2) and two top rail rings (4) in that order. Be sure rail ring gaps are staggered around piston.

If reinstalling original pistons, be sure they are reinstalled on same connecting rod and in same cylinder bore. On some engines, the piston pin is offset slightly in the piston. Make certain these pistons are installed with the word "FRONT" or arrow on top of piston facing front of engine. If these marks have been removed, position piston so the small recess (R—Fig. PR2-14) in pin bore is towards the front.

If installing new pistons, the specified piston height in relation to top surface of cylinder block must be maintained. Pistons are provided with a machining allowance on piston crown to enable necessary material to be removed to obtain specified piston height. To determine amount of material to be removed, install piston and connecting rod assemblies in their respective bores. With piston at TDC, measure distance from top of piston to top of block and compare reading to the following specifications. After machining is completed, mark piston crown to indicate cylinder number and front of piston.

Model	Piston Height Above Cylinder Block
4.99	0.22-0.30 mm (0.0085-0.012 in.)
4.107	0.22-0.30 mm (0.0085-0.012 in.)
4.108	0.05-0.15 mm (0.002-0.006 in.)
4.154 (before S.N. GA...000398C)	0.00-0.10 mm (0.000-0.004 in.)
4.154 (S.N. GA... 000398C and after)	0.10-0.20 mm (0.004-0.008 in.)

Premachined pistons are available for 4.99 engine in three grades to provide specified piston height in block. The grade letter is stamped on piston crown. Service grade F is used to replace production grades "B, D and F"; service grade "L" replaces production grades

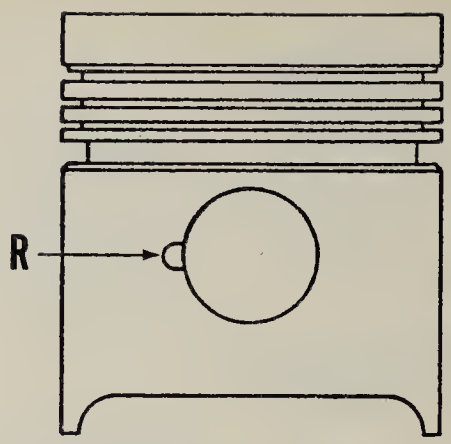


Fig. PR2-14—If marking on top of piston indicating front of piston has been removed by machining the crown, then the side of piston with small recess (R) in pin bore should face front of engine.

"H, J and L", and service grade "P" replaces production grades "N and P". Service grade "F" pistons may also be machined to provide the other two grade heights if desired.

CONNECTING ROD

The connecting rod uses a renewable bushing in the small end. When renewing bushing, use suitable tools to avoid damaging bushing or rod and make sure oil hole in bushing is aligned with oil hole in rod. Bushing must be reamed to final size after installation. Specified bushing inside diameter is 22.24-22.26 mm (0.8757-0.8762 inch) for early 4.99 engines, 23.83-23.84 mm (0.9382-0.9387 inch) for late 4.99 and all 4.107 engines, 27.004-27.005 mm (1.06315-1.0632 inch) for 4.108 engines and 31.76-31.79 mm (1.2505-1.2515 inches) for 4.154 engines. Recommended operating clearance of piston pin in bushing is 0.01-0.03 mm (0.0005-0.0012 inch) for 4.99 and 4.107 engines, 0.0114-0.0178 mm (0.0005-0.0007 inch) for 4.108 engines and 0.01-0.04 mm (0.0005-0.0016 inch) for 4.154 engines.

A precision, insert type bearing is used in the connecting rod big end. Inside diameter of bearing should be 50.838-50.863 mm (2.0015-2.0025 inches) for 4.99, 4.107 and 4.108 engines or 57.16-57.19 mm (2.2504-2.2512 inches) for 4.154 engines. Recommended rod bearing running clearance is 0.036-0.081 mm (0.0014-0.0032 inch) for 4.99, 4.107 and 4.108 engines or 0.04-0.08 mm (0.0016-0.0031 inch) for 4.154 engines.

Connecting rod side clearance on crankshaft should be 0.19-0.27 mm (0.0075-0.0105 inch) for early 4.99 engines, 0.16-0.27 mm (0.0065-0.0105 inch) for late 4.99 and all 4.107 and 4.108 engines and 0.24-0.33 mm (0.0095-0.0131 inch) for 4.154 engines.

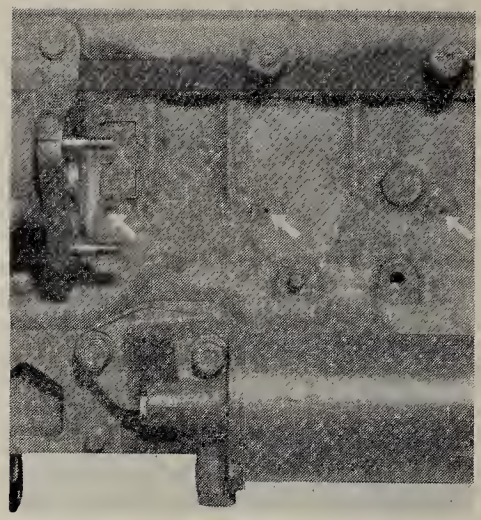


Fig. PR2-15—Vent holes (arrows) are provided in cylinder block between upper and lower cylinder sleeve sealing rings to allow coolant which may leak past upper seal ring to escape.

When reinstalling connecting rods, be sure side marked "FRONT" is facing front of the engine. Make certain locating tabs of bearing inserts are correctly positioned in machined notches of rod and cap. Lubricate bearing surfaces prior to assembly. Manufacturer recommends renewing connecting rod nuts on 4.154 engine whenever they are removed. Tighten connecting rod cap screws or nuts to torque recommended in TIGTENING TORQUES section.

CYLINDER BLOCK AND LINERS

Models 4.99 and 4.107

The cylinder block is equipped with cast iron, wet type, push fit cylinder liners. The liners are sealed at the bottom by two "O" rings (one "O" ring on early 4.99 engines) located in machined recesses in cylinder block. If cylinder liners are going to be removed but reused, identify liners so they can be reinstalled in original cylinder bore and in same relative position.

Use a suitable tool to remove liners. When reinstalling liners, be sure sealing surfaces are smooth and free of any corrosion. Be sure to renew "O" ring seals. Coat liners and "O" rings with soapy water, then hand push liner into cylinder bore until bottomed. When correctly installed, top of liner flange should be between 0.076 mm (0.003 inch) above to 0.025 mm (0.001 inch) below surface of cylinder block.

The area of the cylinder bore between the sealing rings is vented to outside of cylinder block by small holes as shown in Fig. PR2-15. Vent holes allow any coolant which may leak past the upper

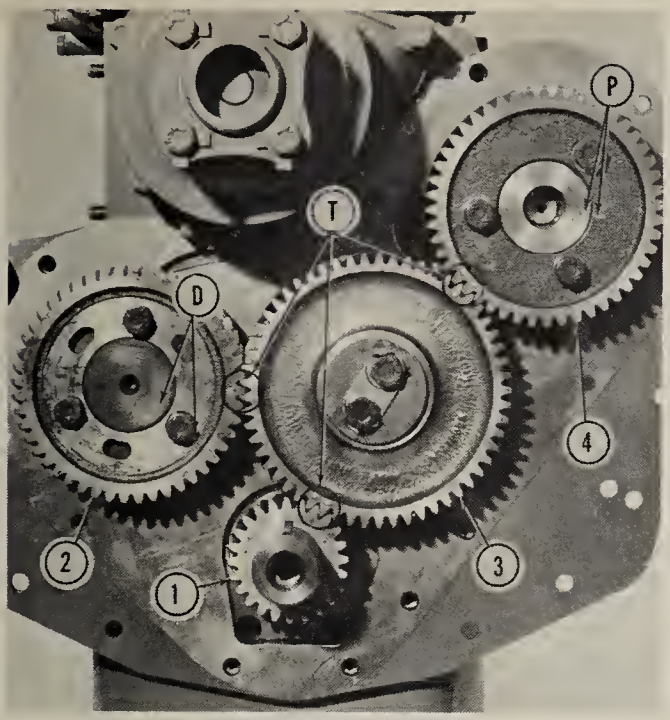


Fig. PR2-16—View of timing gear train used on 4.99, 4.107 and 4.108 engines showing timing marks correctly aligned.

D. Camshaft gear to hub alignment marks
P. Injection pump gear to drive hub alignment marks
T. Gear train timing marks
1. Crankshaft gear
2. Camshaft gear
3. Idler gear
4. Injection pump gear

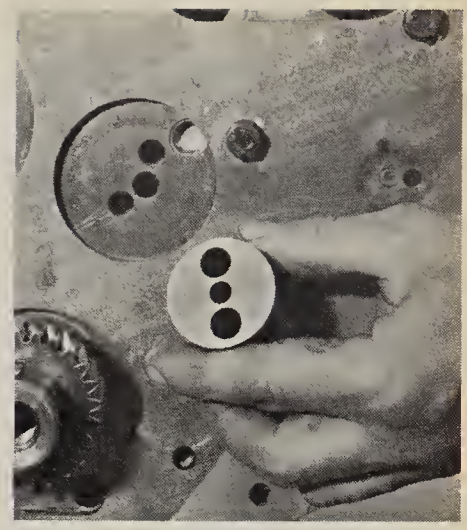


Fig. PR2-17—Cap screw holes in timing idler gear hub are oversized to permit shifting hub position to adjust timing gear backlash on 4.99, 4.107 and 4.108 engines.

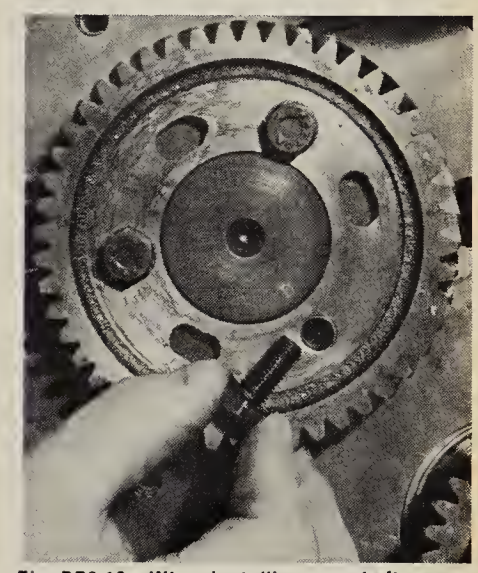


Fig. PR2-18—When installing camshaft gear on 4.99, 4.107 and 4.108 engines, make sure to use round mounting holes in gear and that "D" marks are adjacent to each other.

seal ring to escape rather than entering engine oil pan. Make sure vent holes are open when servicing the cylinder liners. Note that slight leakage of coolant in a newly overhauled engine is normal during initial period of operating, but should stop after seal rings seat.

Inside diameter of liners is prefinished to 76.20-76.225 mm (3.00-3.001 inches) for 4.99 engines and 79.374-79.400 mm (3.125-3.126 inches) for 4.107 engines. Renew liners if bore wear exceeds 0.15 mm (0.006 inch).

Models 4.108 and 4.154

These engines are equipped with renewable, cast iron, dry type, interference fit cylinder liners. The liners for 4.108 engines are thin wall type and must be renewed if excessively worn. The liners used in 4.154 engines may be rebored for installation of 0.76 mm (0.030 inch) oversize pistons.

When checking cylinder liner wear, each one should be measured at top, center and bottom at right angle and parallel to centerline of cylinder block thereby giving six readings for each cylinder. Standard inside diameter of liners is 79.375-79.40 mm (3.125-3.126 inches) for 4.108 engines and 88.92-88.95 mm (3.501-3.502 inches) for 4.154 engines. Maximum allowable bore wear for either engine is 0.15 mm (0.006 inch).

To remove cylinder liners, use a suitable press and shouldered plate to push old liners out from the bottom through top of cylinder block. Inspect cylinder block bore for damage. Bore diameter should be 82.525-82.550 mm (3.249-3.250 inches) for 4.108 engines and 96.84-96.86 mm (3.8125-3.8135 inches) for 4.154 engines. On 4.108 engines, cylinder block bore may be bored oversize to remove damage and a 0.25 mm (0.010 inch) oversize outside diameter liner installed. If an oversize liner is installed at the factory, the liner oversize is stamped on top of cylinder block between the liner and edge of block.

To install new liners, lightly lubricate outside of liner with engine oil. When properly installed, top of liner must protrude above surface of cylinder block 0.584-0.686 mm (0.023-0.027 inch) on 4.108 engines. A solid stop of the correct thickness should be positioned on top of cylinder block to limit press travel and establish correct liner protrusion. On 4.154 engines, liner flange seats against counterbore in top of cylinder block. When liner is correctly installed, top of liner collar should protrude 0.66-0.79 mm (0.026-0.031 inch) above top surface of cylinder block. On both engines, cylinder liner inner diameter must be bored and finish honed to final desired dimension after installation.

TIMING GEARS

Models 4.99, 4.107 and 4.108

The timing gear train consists of the crankshaft gear, camshaft gear, injection pump gear as shown in Fig. PR2-16. Due to the odd number of idler gear teeth, timing marks will align only once in 38 crankshaft revolutions, therefore, nonalignment of timing marks does not necessarily mean the gears are mistimed.

NOTE: Before removing timing gears, first remove the rocker arm cover and rocker shaft assembly to prevent pistons from contacting valves if crankshaft is turned while gears are removed.

Idler gear (3) and hub are retained by two cap screws. Idler gear bushing bore diameter when new is 39.687-39.728 mm (1.5625-1.5641 inches). Idler hub diameter is 39.654-39.668 mm (1.5612-1.5619 inches) and desired running clearance is 0.008-0.041 mm (0.0003-0.0016 inch). When reinstalling idler gear, be sure timing marks (T) are properly aligned. Oversize mounting holes (Fig. PR2-17) are provided in idler hub to obtain necessary backlash adjustment by shifting position of hub. Specified backlash between idler and other three gears is 0.038-0.064 mm (0.0015-0.0025

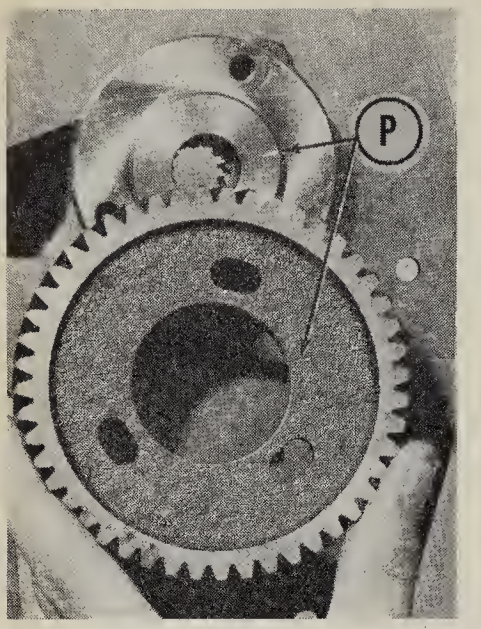


Fig. PR2-19—When installing injection pump drive gear on 4.99, 4.107 and 4.108 engines, be sure scribe marks (P) are aligned.

inch). Tighten mounting cap screws to 49 N·m (36 ft.-lbs.). Check idler gear end play using a feeler gage. Recommended end play is 0.076-0.208 mm (0.003-0.008 inch) with a wear limit of 0.25 mm (0.010 inch).

Camshaft gear (2–Fig. PR2-16) is attached to camshaft flange with three cap screws. When reinstalling gear, make certain the stamped "D" markings on gear and hub are aligned and cap screws are installed in round holes (not the oblong holes) as shown in Fig. PR2-18. Tighten the mounting screws to 27 N·m (20 ft.-lbs.).

The injection pump drive gear (4–Fig. PR2-16) is retained to pump drive hub with three cap screws. Attaching holes in gear are slotted as shown in Fig. PR2-19. When reinstalling gear, be sure to align scribe lines (P) on hub and gear, then tighten retaining cap screws to 27 N·m (20 ft.-lbs.). Note that replacement pump drive gear is not marked and must be installed and marked as follows: Turn crankshaft until timing gear marks are aligned and number 1 piston is at TDC on compression stroke. Remove fuel pump gear, then turn crankshaft to position number 1 piston at static timing position as outlined in INJECTION PUMP TIMING section. Turn pump drive hub until scribe line on rotor marked "A" (hydraulic governor pump) is aligned with square end of pump timing snap ring. Install new injection pump gear making sure timing gears and pump shaft do not move. Recheck injection pump static timing and scribe timing line on new gear to coincide with mark on hub if timing is correct. Rotate crankshaft so number 1 piston is at TDC, then stamp two dots on the new

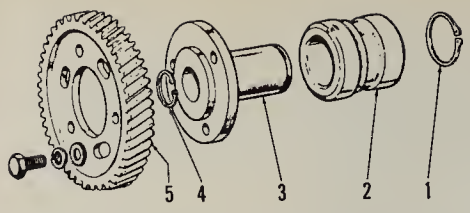


Fig. PR2-20—Exploded view of injection pump drive gear, hub and bushing assembly used on engines equipped with an injection pump with a hydraulic governor.

1. Snap ring
2. Bushing
3. Drive hub
4. Snap ring
5. Gear

gear to coincide with the single dot on idler gear (Fig. PR2-16).

To remove injection pump drive hub (3–Fig. PR2-20), first remove pump drive gear and injection pump. Remove retaining snap ring and withdraw drive hub. Inspect bushing (2) for wear. Inside diameter of bushing should be 33.34-33.78 mm (1.3125-1.3135 inches) and outside diameter of drive hub is 33.287-33.312 mm (1.3105-1.3115 inches). Desired running clearance of hub in bushing is 0.079-0.129 mm (0.0031-0.0051 inch). Bushing is a press fit in cylinder block bore. With drive hub reinstalled, check end play with a feeler gage between front face of bearing and rear face of drive hub. End play should be within the limits of 0.051-0.254 mm (0.0052-0.010 inch).

The crankshaft gear is an interference fit on crankshaft and is located by a key. Use a suitable puller to remove gear.

Model 4.154

The timing gear train consists of the crankshaft gear, camshaft gear, injection pump gear and an idler gear that connects the other three gears as shown in Fig. PR2-21. When timing marks (T) are aligned properly, number 1 piston will be at TDC on compression stroke. However, due to the odd number of teeth on the idler gear, the marks will not align every rotation of crankshaft when number 1 piston is at TDC on compression stroke. Nonalignment of timing marks does not necessarily mean the gears are mistimed.

NOTE: To reinstall timing gears, the rocker arm shaft must be removed so pistons will not contact valves when crankshaft is turned. Since cap screws securing rocker shaft are also securing cylinder head, engine coolant should be drained, injectors should be removed and cap screws should be loosened gradually to prevent distortion.

The idler gear is attached by two nuts and the idler hub is an interference fit in the timing case. Idler gear bushing inner

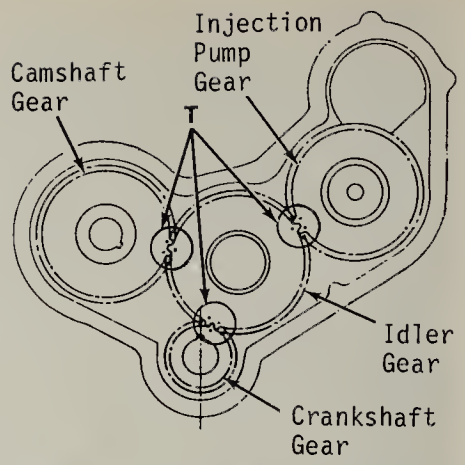


Fig. PR2-21—View of gear train with timing marks (T) correctly aligned for 4.154 engine.

diameter when new is 44.01-44.04 mm (1.7327-1.7337 inches) and idler hub outer diameter is 43.95-43.97 mm (1.7303-1.7313 inches). Desired running clearance of gear on hub is 0.03-0.09 mm (0.0014-0.0034 inch). Recommended idler gear end play is 0.15-0.30 mm (0.006-0.012 inch) with a wear limit of 0.38 mm (0.015 inch). Before reinstalling idler hub, be sure oil holes in cylinder block and hub are open. Install idler gear aligning timing marks (T) as shown in Fig. PR2-21. Renew self-locking retaining nuts and tighten to 28 N·m (21 ft.-lbs.).

The camshaft gear is an interference fit on the camshaft. Use a suitable puller to remove gear. When reinstalling gear, draw the gear onto the shaft using the retaining washer and cap screw. Tighten cap screw to 68 N·m (45 ft.-lbs.).

The injection pump drive gear is retained by three cap screws. On engines equipped wtih an injection pump with a hydraulic governor, gear is properly located by aligning scribe marks on the gear and drive hub. On mechanical governor pumps, gear is doweled to pump shaft. When installing a new pump gear with hydraulic governor pump, the gear is supplied without timing marks. To install and time new gear, turn crankshaft until number 1 piston is at TDC on compression storke. Remove injection pump gear, then turn crankshaft to position number 1 piston at static timing position as outlined in INJECTION PUMP TIMING section. Remove fuel return plate from injection pump and turn pump drive hub until scribe line on rotor marked "A" is aligned with square end of pump gear. Install new injection pump gear making sure timing gears and pump shaft do no move. Recheck injection pump static timing. If timing is correct, rotate crankshaft so number 1 piston is at TDC. Scribe a line on gear to coincide with line on drive hub and stamp two

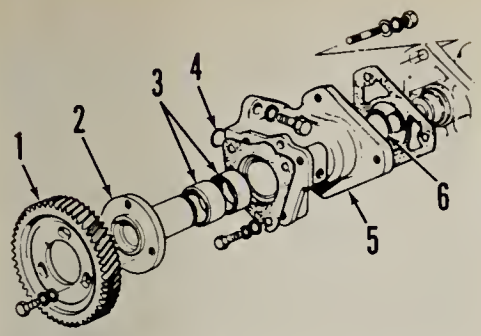


Fig. PR2-22—Exploded view of injection pump drive hub and adapter housing used on 4.154 engines equipped with an injection pump with a hydraulic governor.

1. Drive gear
2. Drive hub
3. Bushings
4. "O" ring
5. Adapter housing
6. Snap ring

dots on gear to coincide with the single dot on idler gear.

Backlash between idler gear and fuel pump gear on hydraulic governor engines is adjusted by loosening the fuel pump adapter housing mounting screws and shifting housing as necessary. Recommended backlash is 0.10-0.20 mm (0.004-0.008 inch). Gear backlash is not adjustable on mechanical governor engines.

To remove pump drive hub (hydraulic governor pumps), first remove pump drive gear and injection pump. Remove snap ring (6—Fig. PR2-22) from rear of drive hub (2), then withdraw hub forward from housing (5). Inspect bushings (3) located in adapter housing for wear and renew if necessary. Inside diameter of bushings when new is 31.75-31.79 mm (1.250-1.2516 inches) and outside diameter of hub is 31.70-31.72 mm (1.248-1.249 inches). Desired running clearance of hub in bushings is 0.02-0.09 mm (0.001-0.0035 inch). With drive hub reinstalled, check end play. Recommended end play is 0.13-0.28 mm (0.005-0.011 inch). Be sure "O" ring (4) is renewed if adapter housing (5) is removed.

The crankshaft gear is a light interference fit on crankshaft and is located by a key. Use a suitable puller to remove gear.

CAMSHAFT

To remove the camshaft, it will be necessary to mount the engine on a suitable engine stand so it can be turned upside down. The purpose of this is to allow the mushroom type cam followers to move away from the cam lobes to provide clearance for camshaft removal. If this cannot be done, then provision should be made to secure the cam followers in their uppermost position through use of suitable retaining clips.

Inspect all parts for scoring, wear and other damage. Renew camshaft if journal wear exceeds 0.05 mm (0.002 inch). Renew components if they fail to meet the following specified values.

Models 4.99, 4.107 and 4.108

Camshaft journal diameter:
- No. 1 ..... 45.491-45.517 mm (1.791-1.792 in.)
- No. 2 ..... 45.237-45.263 mm (1.781-1.782 in.)
- No. 3 ..... 45.034-45.060 mm (1.773-1.774 in.)

Cylinder block bore diameter:
- No. 1 ..... 45.568-45.606 mm (1.794-1.7955 in.)
- No. 2 ..... 45.314-45.390 mm (1.784-1.787 in.)
- No. 3 ..... 45.110-45.161 mm (1.776-1.778 in.)

Journal clearance:
- No. 1 ..... 0.051-0.114 mm (0.002-0.0045 in.)
- No. 2 ..... 0.051-0.152 mm (0.002-0.006 in.)
- No. 3 ..... 0.051-0.127 mm (0.002-0.005 in.)

Cam follower bore diameter ..... 14.275-14.307 mm (0.562-0.563 in.)

Cam follower outer diameter ..... 14.224-14.249 mm (0.560-0.561 in.)

Cam follower clearance in bore .... 0.025-0.082 mm (0.001-0.003 in.)

Thrust plate thickness ..... 4.060-4.115 mm (0.160-0.162 in.)

Camshaft end play:
- Desired ..... 0.076-0.228 mm (0.003-0.009 in.)
- Maximum ..... 0.51 mm (0.020 in.)

Model 4.154

Camshaft journal diameter:
- No. 1 ..... 51.91-51.94 mm (2.0437-2.0448 in.)
- No. 2 ..... 51.66-51.69 mm (2.0339-2.0350 in.)
- No. 3 ..... 51.41-51.44 mm (2.0241-2.0252 in.)
- No. 4 ..... 51.16-51.19 mm (2.0142-2.0154 in.)

Cylinder block bore diameter:
- No. 1 ..... 52.0-52.03 mm (2.0472-2.0484 in.)
- No. 2 ..... 51.75-51.78 mm (2.0374-2.0386 in.)
- No. 3 ..... 51.5-51.53 mm (2.0275-2.0287 in.)
- No. 4 ..... 51.25-51.28 mm (2.0177-2.0189 in.)

Journal clearance:
- All journals ..... 0.06-0.12 mm (0.0024-0.0047 in.)

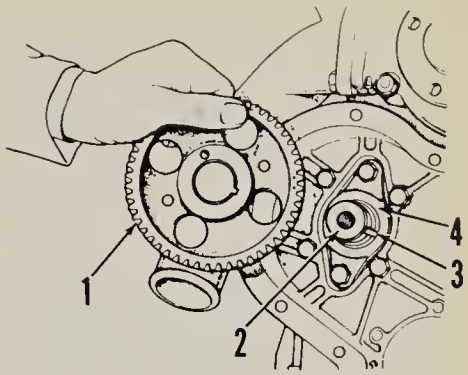


Fig. PR2-23—On 4.154 engines, camshaft gear (1) is keyed to camshaft and retained by a cap screw and washer.

1. Camshaft gear
2. Camshaft
3. Key
4. Thrust plate

Thrust plate thickness ... 5.92-6.00 mm (0.233-0.236 in.)

Camshaft end play:
- Desired ..... 0.03-0.18 mm (0.0012-0.0071 in.)
- Maximum ..... 0.38 mm (0.015 in.)

Thoroughly lubricate cam followers and camshaft with engine oil prior to reassembly. Reinstall cam followers and camshaft in opposite order of removal. Be sure to align timing gear marks.

OIL PUMP

The rotary type oil pump fits into a machined bore in cylinder block and is driven through spiral gears from the camshaft. The oil pressure relief valve is contained within the oil pump end cover (Fig. PR2-30). Normal oil pressure with engine at full speed and normal operating temperature should be 207-414 kPa (30-60 psi).

To remove oil pump assembly, first drain oil and remove oil pan. Disconnect

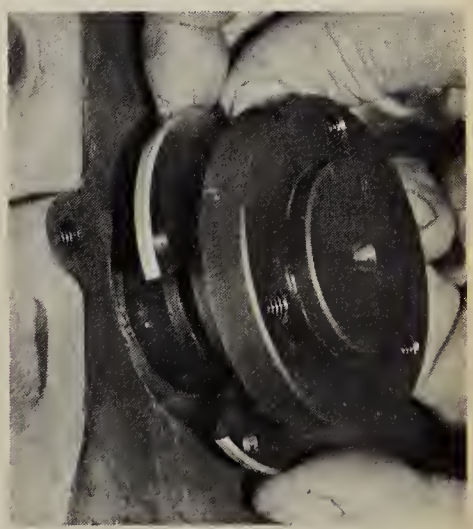


Fig. PR2-24—On 4.99, 4.107 and 4.108 engines, remove thrust washer halves as camshaft is withdrawn.

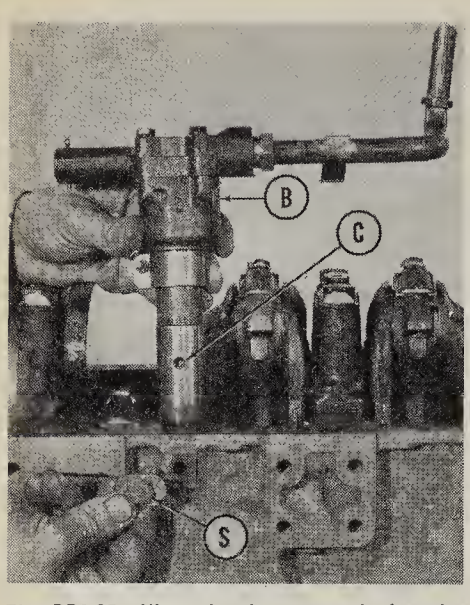


Fig. PR2-25—View showing removal of engine oil pump.

B. Pump body
C. Locating hole
S. Set screw

Fig. PR2-26—Oil pump rotor clearance may be measured with a feeler gage as shown. Refer to text for specified clearance.

Fig. PR2-27—Use a feeler gage to measure clearance between outer rotor and oil pump body. Refer to text.

Fig. PR2-28—End clearance of rotors may be checked using a straightedge and feeler gage as shown.

oil pressure pipe. Remove pump locating cap screw (S – Fig. PR2-25) from side of cylinder block, then withdraw pump assembly.

Oil pump spiral drive gear is a press fit on shaft and is not keyed or pinned. Gear can be removed using a suitable puller or press. Pump rotors, body and cover are available as a unit assembly only. Check rotor clearance as shown in Figs. PR2-26 and PR2-27. Measure end clearance between rotors and machined surface of pump body as shown in Figs. PR2-26 and PR2-27. Measure end clearance between rotors and machined surface of pump body as shown in Fig. PR2-28. Refer to the following table for specified pump clearances.

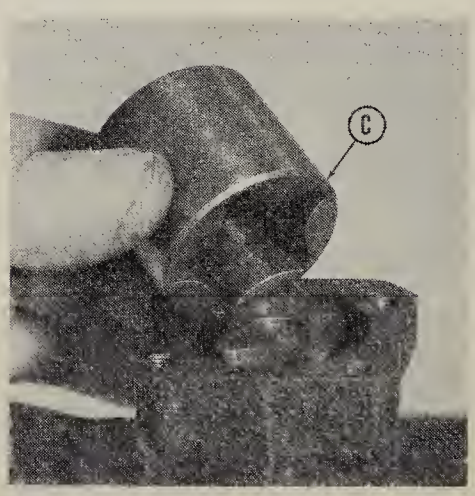


Fig. PR2-29—When reinstalling oil pump outer rotor, be sure chamfered edge (C) is towards bottom of housing bore.

Models 4.99, 4.107 and 4.108

Inner rotor to outer rotor	0.013-0.063 mm (0.0005-0.0025 in.)
Outer rotor to pump body	0.28-0.33 mm (0.011-0.013 in.)
End clearance:	
Inner rotor	0.038-0.076 mm (0.0015-0.0030 in.)
Outer rotor	0.013-0.063 mm (0.0005-0.0025 in.)

Model 4.154

Inner rotor to outer rotor	0.05-0.15 mm (0.002-0.006 in.)
Outer rotor to pump body	0.13-0.25 mm (0.0052-0.010 in.)
End clearance (both rotors)	0.02-0.13 mm (0.001-0.005 in.)

When reassembling pump, make certain outer rotor is installed with chamfered edge down as shown in Fig. PR2-29. Be sure pump rotates smoothly after assembly. Prime the pump with engine oil before reinstalling. Before starting engine, crank with starter motor with injection pump in "stop" position for about 20 seconds to allow pump and pipes to fill with oil. Start engine and run at low speed until normal oil pressure is obtained.

CRANKSHAFT AND BEARINGS

Models 4.99, 4.107 and 4.108

The crankshaft operates in three precision, insert type main bearings. End thrust is taken by thrust washers located on either side of rear main bearing.

NOTE: On late 4.99 and 4.107 engines, the annular oil groove in the cylinder block main bearing bores has been deleted. Late style main bearing inserts have an annular groove machined in the bearing (inner) face along the centerline of the oil feed hole. The later style bearing inserts may be used in both early and late style engines, but under no circumstances should early style bearings (without grooves) be installed in late style cylinder block (without grooves).

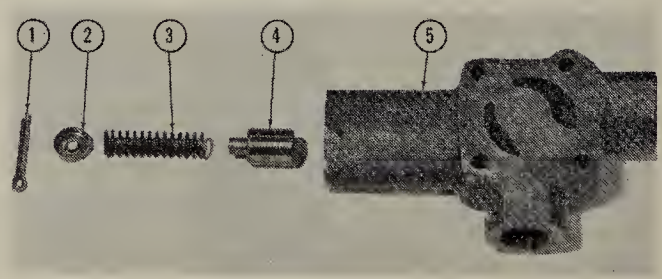


Fig. PR2-30—Oil pump relief valve is contained within oil pump end cover.

1. Cotter pin
2. Retainer
3. Spring
4. Valve poppet
5. Pump end cover

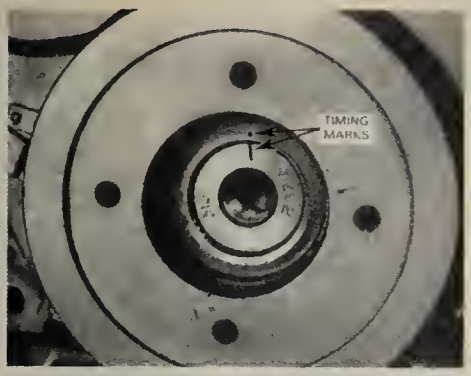
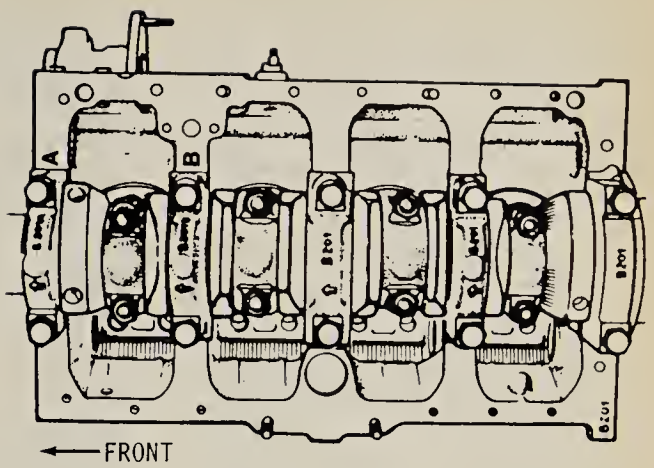


Fig. PR2-31—On some engines, crankshaft pulley has a timing mark which must be aligned with timing mark on end of crankshaft.

Fig. PR2-32—View of main bearing caps on 4.154 engine. All caps are identified by a serial number that corresponds with serial number stamped on rear bottom surface of cylinder block. An arrow is cast into each cap and should point to front of engine.



Crankshaft main journal standard diameter is 57.099-57.112 mm (2.2480-2.2488 inches) for front and center journals and 57.086-57.099 mm (2.2475-2.2480 inches) for rear journal. If journals are out-of-round in excess of 0.01 mm (0.0005 inch) or wear exceeds 0.03 mm (0.001 inch), crankshaft should be reground or renewed. Recommended main bearing running clearance is 0.051-0.089 mm (0.002-0.0035 inch) for front and center bearings and 0.063-0.102 mm (0.0025-0.004 inch) for rear bearing.

Crankpin standard diameter is 50.78-50.80 mm (1.9993-2.0001 inches). Crankpin wear limit is 0.03 mm (0.001 inch) and out-of-round limit is 0.01 mm (0.0005 inch). Recommended rod bearing running clearance is 0.036-0.081 mm (0.0014-0.0032 inch).

Main journals and crankpins may be reground to 0.25, 0.51 and 0.76 mm (0.010, 0.020 and 0.030 inch) undersize. However, the crankshafts used in most 4.108 and some 4.107 engines are Tufftrided and must be properly rehardened after grinding. If facilities are not available for Tufftriding, the 20-hour nitriding process may be substituted. If neither of these processes can be performed, crankshaft must be renewed. The Tufftrided crankshafts can be identified by their part number stamped on nose or number 1 web. The following part numbers are Tufftrided: 31315741, 31315827, 31315828, 31315829, 31315831, 31315836, 31315838, 31316111, 31316112, 31316113, 31316114, 31316122, 31316128 and 31316121. All other crankshafts used are induction hardened and do not require rehardening after regrinding.

When reinstalling crankshaft, note that main bearing caps are numbered and are not interchangeable. Tighten main bearing cap mounting cap screws to 115 N·m (85 ft.-lbs.). Be sure crankshaft turns freely. Check crankshaft end play using a feeler gage. Recommended end play is 0.051-0.381 mm (0.002-0.015 inch) and maximum allowable end play is 0.51 mm (0.020 inch). Thrust washers are available in 0.19 mm (0.0075 inch) oversize to adjust end play if necessary. Renew front and rear oil seals if necessary. When reinstalling crankshaft pulley on late engines, the pulley is marked with a punch mark (Fig. PR2-31) which must be aligned with scribed line on crankshaft nose. Tighten pulley retaining cap screw as follows: On 4.108 engines with 39.6 mm (1.56 inch) long screw and on all 4.99 and 4.107 engines, tightening torque is 203 N·m (150 ft.-lbs.). On 4.108 engines with cadmium plated (shiny finish) retaining screw, torque is 250 N·m (190 ft.-lbs.). On 4.108 engines using a phosphated (dull black finish) cap screw, torque is 310 N·m (230 ft.-lbs.). Tighten flywheel retaining screws to 81 N·m (60 ft.-lbs.).

Model 4.154

The crankshaft is supported in five precision, insert type main bearings. End thrust is taken by thrust washers located on both sides of center main bearing.

Crankshaft main journal standard diameter is 69.81-69.82 mm (2.7485-2.7488 inches). Recommended main bearing running clearance is 0.06-0.11 mm (0.0025-0.0045 inch). Crankpin standard diameter is 57.10-57.12 mm (2.2485-2.249 inches). Recommended rod bearing runnning clearance is 0.04-0.08 mm (0.0015-0.003 inch). If main journals or crankpins are out-of-round in excess of 0.01 mm (0.0005 inch) or wear exceeds 0.03 mm (0.001 inch), crankshaft should be reground or renewed. Main journals and crankpins may be reground 0.25, 0.51 and 0.76 mm (0.010, 0.020 or 0.030 inch) undersize.

When reinstalling crankshaft, note that main bearing caps are identified in relation to the cylinder block by a serial number stamped on each cap and also bottom face of cylinder block (Fig. PR2-32). An arrow is cast into each cap and must point towards front of engine for correct installation. Number 1 cap (beginning at front) is stamped with an "A", number 2 cap is stamped with a "B". Corresponding letters are stamped on cylinder block. The third cap carries the thrust washers and is easily identified. The number 4 cap has no identification marks, but it is similar to number 1 and 2 caps which are identified, so its position is predetermined. The number 5 cap is the rear main, which is drilled and tapped to hold the bottom half of oil seal retainer, and therefore, should not be mistaken for any of the other caps. Tighten bearing cap mounting screws to 115 N·m (85 ft.-lbs.). Renew front and rear oil seals as outlined in the following CRANKSHAFT OIL SEALS section. Be sure timing mark on crankshaft pulley is aligned with mark on end of crankshaft. Tighten pulley retaining screw to 167 N·m (123 ft-lbs.). Tighten flywheel retaining screws to 108 N·m (80 ft.-lbs.)

CRANKSHAFT OIL SEALS

FRONT SEAL. The front seal is located in the timing gear front cover. On early 4.99, 4.107 and 4.108 engines, a black nitrile oil seal and a crankshaft oil thrower were used. On late engines, a red silicon seal with front dust lip is used and a spacer is used in place of oil thrower. When using red silicone seal to replace early black nitrile seal, the oil thrower must also be removed and replaced with spacer. On all engines, press new seal into cover from the front making sure spring-loaded lip faces inward. On 4.99, 4.107 and 4.108 engines, press

seal in until it bottoms against front cover flange. On 4.154 engines, press seal in until front face of seal is 6.35-7.62 mm (0.250-0.300 inch) below front surface of cover as shown at (X–Fig. PR2-33). Be sure to lubricate seal lip and crankshaft with oil before reinstalling.

REAR SEAL. The rear seal consists of rope type seal which fits into grooves of a two-piece retainer. The retainer halves are bolted around rear flange of crankshaft. The rope type seal is precision cut to length and must be installed in retainer halves so 0.25-0.50 mm (0.010-0.020 inch) of the seal projects from each end of the retainer halves. Use a round bar to roll and compress seal into retainer groove (Fig. PR2-34). Lubricate the exposed surface of seal with graphite grease before reinstalling. Apply sealing compound to gasket surfaces, then reinstall retainer halves and install all mounting cap screws finger tight. Tighten retainer clamping bolts to initial torque of 8 N·m (6 ft.-lbs.), then tighten seal retainer mounting screws to 16 N·m (12 ft.-lbs.). Finally, tighten clamping bolts to final torque of 16 N·m (12 ft.-lbs.).

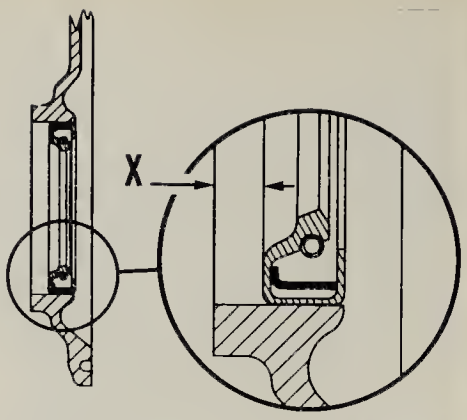


Fig. PR2-33—When renewing front oil seal on 4.154 engines, press seal into timing gear cover until distance (X) from front of cover to front of seal is 6.35-7.62 mm (0.250-0.300 inch).

Fig. PR2-34—Use a round bar to compress rope type rear seal into retainer groove when renewing seal.

PETTER

LISTER-PETTER
555 E. 56 Highway
Olathe, Kansas 66061

Model	No. Cyls.	Bore	Stroke	Displ.
AA1	1	69.85 mm (2.75 in.)	57.15 mm (2.25 in.)	220 cc (13.4 cu. in.)
AB1	1	76.2 mm (3 in.)	57.15 mm (2.25 in.)	261 cc (15.9 cu. in.)
AC1	1	76.2 mm (3 in.)	66.68 mm (2.625 in.)	304 cc (18.5 cu. in.)
AC1Z, AC1ZS	1	76.2 mm (3 in.)	66.68 mm (2.625 in.)	304 cc (18.5 cu. in.)
AC2	1	76.2 mm (3 in.)	66.68 mm (2.625 in.)	606 cc (37 cu. in.)

All engines are four-stroke, air cooled, direct injection diesels. Crankshaft rotation at flywheel is counterclockwise on AC2 and AC1Z engines. On all other engines, crankshaft rotation is clockwise viewed at the flywheel.

MAINTENANCE

LUBRICATION

Recommended engine oil is SAE 10W for temperatures below 5°C (41°F), SAE 20W-20 for temperatures between 5°C (41°F) and 30°C (86°F) and SAE 30 for temperatures above 30°C (86°F). SAE 10W-30, 10W-40, 15W-40 and 20W-40 multigrade oils are also approved for use. All oil used must meet specification MIL-L46152-B.

NOTE: Use of oil meeting API specification CD or MIL-L-2104C specification is not recommended in new or overhauled engines until after the first oil change, or in engines running at light load in low ambient temperatures. Oil meeting CD and MIL-L-2104C specifications should be used only in engines operating at high loads, speeds and ambient temperatures.

Manufacturer recommends renewing oil and oil filter after the first 20 hours of operation on a new or overhauled engine. Thereafter, oil and oil filter should be renewed at intervals of 250 operating hours. Crankcase capacity is approximately 1.9 liters (3.25 pints) for AA1 and AB1 engines, 2.7 liters (4.75 pints) for AC1, AC1Z and AC1ZS engines or 3.7 liters (6.5 pints) for AC2 engine.

FUEL SYSTEM

FUEL FILTER. On engines equipped with a mounted fuel tank, the fuel filter is located in the bottom of the fuel tank. On engines using a remote fuel tank a separately mounted fuel filter should be used. In either case, manufacturer recommends renewing fuel filter after 1000 hours of operation or sooner if loss of power is evident. After renewing fuel filter, air must be bled from fuel system as outlined in the following paragraph.

BLEED FUEL SYSTEM. Most engines are equipped with a self-bleeding pipe in place of fuel pump vent screw (1 – Fig. PE-1) and no action is required to bleed air from the fuel system. If not equipped with a self-bleeding system, proceed as follows: Loosen vent screws on top of filter housing on separately mounted filter. When air-free fuel flows from vents, retighten screws. Loosen vent screw on fuel injection pump (Fig. PE-1) and actuate priming lever of fuel transfer pump (if so equipped). When fuel flows steadily from vent, retighten vent screw. If engine fails to start at this point, loosen high pressure fuel line fitting at the injector. With pump controls in "RUN" position, crank engine until fuel is discharged from loosened fuel line fitting. Retighten fitting and start engine.

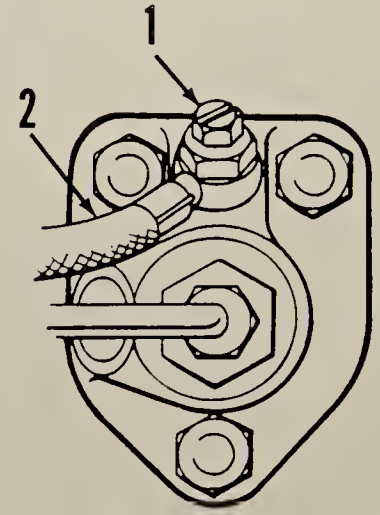


Fig. PE-1—View of air vent screw (1) located on injection pump fuel supply line (2) for engines not equipped with self-bleeding system.

ENGINE SPEED ADJUSTMENT

FIXED SPEED CONTROL. To adjust maximum engine speed setting on engines with fixed speed control, loosen locknut (1 – Fig. PE-2) and turn adjusting screw (2) in to increase speed or out to decrease speed. The engine maximum no-load speed should be set at 4 percent above the rated full-load speed as indicated on engine identification plate.

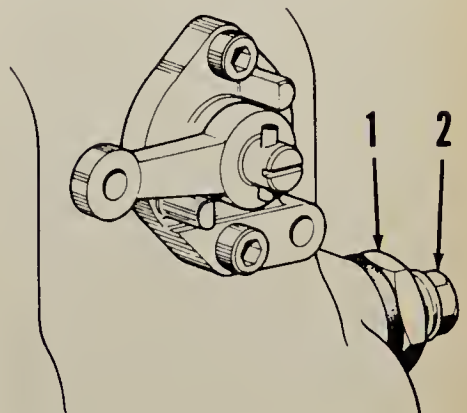


Fig. PE-2—View of engine fixed speed control, locknut (1) and adjusting screw (2). Refer to text.

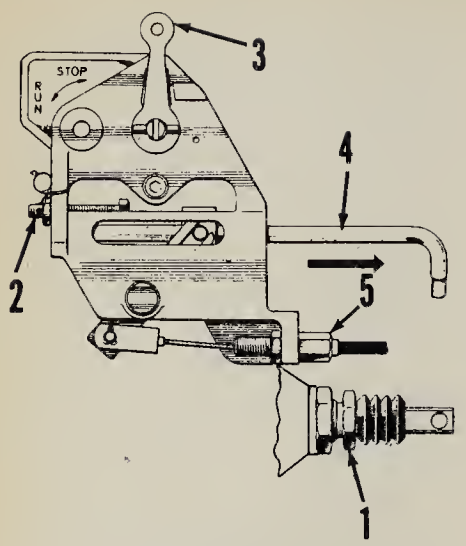


Fig. PE-3—Variable speed control (Type 1) adjustment points. Refer to text.

1. Idle adjuster
2. Maximum speed adjusting screw
3. Speed control lever
4. Rod
5. Cable adjuster

VARIABLE SPEED CONTROL (TYPE 1). Engine low idle speed is adjusted by turning adjuster (1 – Fig. PE-3) in or out. Recommended low idle speed is 1200 rpm.

Engine maximum no-load speed setting is adjusted using screw (2 – Fig. PE-3). Maximum no-load speed should be set 8 percent above the rated full-load speed indicated on the engine name plate. Turn screw clockwise to increase speed or counterclockwise to decrease speed. Be sure to install a new seal wire through the screw to secure adjustment.

To adjust control cable, pull rod (4) in direction of arrow. Then, turn adjuster (5) until there is a small amount of slack in the inner cable. The speed control lever (3) should be able to move slightly before the inner cable begins to move the speed control rod.

VARIABLE SPEED CONTROL (TYPE 2). With speed control in idle postion (direction of arrow), adjust low idle speed as follows: Loosen locknut (1 – Fig. PE-4) and turn adjuster (2) in to increase speed or out to decrease speed. Recommended idle speed is 1200 rpm.

Move speed control to full speed position. Loosen locknut (5) and turn adjuster (4) out to increase speed or in to decrease speed. Maximum no-load speed should be set at 8 percent above full-load speed setting as specified on engine name plate. Install a new seal wire on adjusting screw to secure adjustment.

To adjust control cable, move speed control to idle position. Turn cable adjuster (6) until there is a small amount of slack in the inner cable. Speed control lever should move slightly before the inner cable begins to move the plunger.

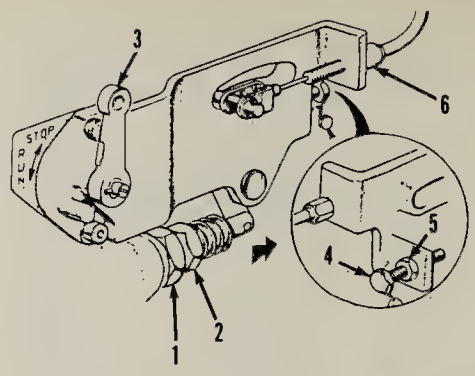


Fig. PE-4—Variable speed control (Type 2) adjustment points. Refer to text.

1. Locknut
2. Idle adjuster
3. Speed control lever
4. Maximum speed adjusting screw
5. Locknut
6. Cable adjuster

TWO-SPEED CONTROL. To adjust low idle speed, move control rod (9 – Fig. PE-5) to idle position and loosen locknut (1). Turn adjuster (2) in to increase speed or out to decrease speed. Recommended idle speed is 1200 rpm.

To adjust maximum speed setting, first loosen locknut (5) and turn stop screw (4) out to allow full movement of control rod. Lift control rod up and over notch in bracket (8) so adjusting nut (6) is against bracket. Loosen jam nut (7), then turn adjusting nut to move rod in direction of arrow "A" to decrease speed or in opposite direction "B" to increase speed. Maximum no-load speed should be set at 8 percent above rated full-load speed indicated on engine name plate. Turn stop screw (4) in until it contacts operating arm (3), then back screw out sufficiently to allow movement of control rod from full idle speed position. Tighten locknut (5) and install a new seal wire.

VARIABLE AND TWO-SPEED CONTROL. To adjust low idle speed, loosen set screw (3 – Fig. PE-6) in idle stop (4). Move control rod (3) in direction of arrow to increase speed or in opposite direction to decrease speed. Recommended low idle speed is 600 rpm. Move idle stop against bracket (8) and retighten set screw.

To adjust maximum no-load speed, move variable speed control (1) to full speed position or two-speed knob (2) to "RUN" position. Loosen locknuts (7) and turn adjusting screw (6) in to increase speed or out to decrease speed. Maximum no-load speed should be set at 8 percent above rated full-load speed specified on engine name plate. Tighten locknuts and install a new seal wire on adjusting screw.

With speed control in low idle position, adjust cable adjuster (9) until there is a small amount of slack in inner cable. The

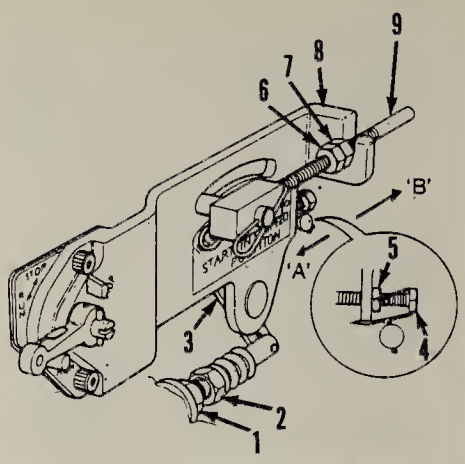


Fig. PE-5—Two-speed control adjustment points. Refer to text.

1. Locknut
2. Low idle adjuster
3. Operating arm
4. Maximum speed stop screw
5. Locknut
6. Adjusting nut
7. Jam nut
8. Bracket
9. Control rod

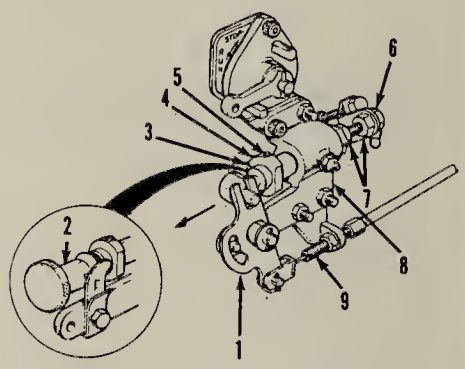


Fig. PE-6—Variable and two-speed control linkage adjustment points. Refer to text.

1. Variable speed lever
2. Two-speed knob
3. Control rod
4. Stop plate
5. Set screw
6. High speed adjusting screw
7. Locknuts
8. Bracket
9. Cable adjuster

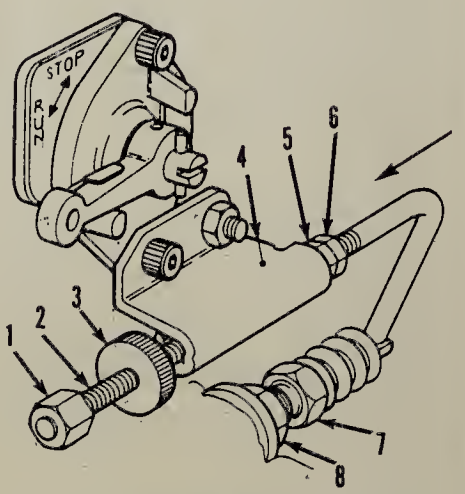


Fig. PE-7—View of knurled nut operated variable speed control. Refer to text for adjustment procedure.

1. Locknut
2. Operating rod
3. Knurled nut
4. Bracket
5. Maximum speed adjusting nut
6. Jam nut
7. Idle speed adjuster
8. Locknut

control lever should move slightly before inner cable begins to move plunger.

VARIABLE SPEED CONTROL (KNURLED NUT TYPE). To adjust low idle speed, move locknut (1–Fig. PE-7) and knurled nut (3) to end of control rod (2). Loosen locknut (8) and turn adjuster (7) in to increase speed or out to decrease speed. Recommended low idle speed is 1200 rpm.

To adjust maximum speed setting, loosen locknut (6) and move control rod in direction of arrow until adjusting nut (5) is against bracket (4). Turn adjusting nut clockwise to decrease speed or counterclockwise to increase speed. Maximum no-load speed setting should be 8 percent higher than rated full-load speed indicated on engine name plate. Set engine speed to required operating speed using the knurled nut.

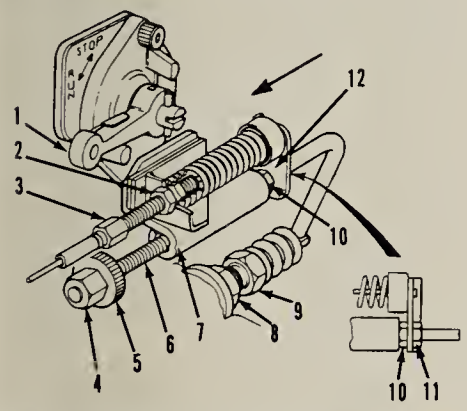


Fig. PE-8—View of spring assisted, cable operated variable speed control. Refer to text for adjustment procedure.

1. Speed control lever
2. Locknut
3. Cable adjuster
4. Locknut
5. Knurled nut
6. Control rod
7. Bracket
8. Locknut
9. Low idle adjuster
10. Maximum speed adjusting nut
11. Locknut
12. Plate

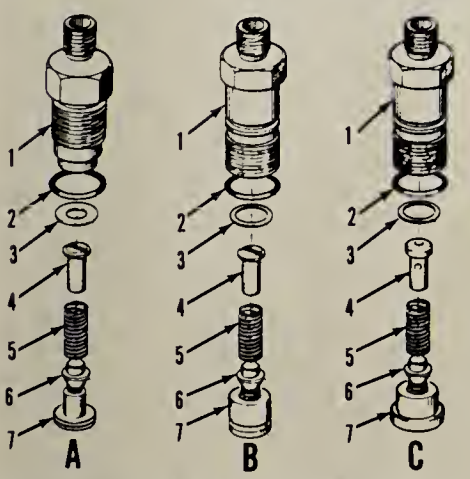


Fig. PE-9—Exploded view of different styles of delivery valve used in (A) Bryce "A" and "B" series pumps, (2) Bryce "E" series pumps and (C) I.E.S.A. type pumps.

1. Delivery union body
2. "O" ring
3. Gasket
4. Spring guide
5. Spring
6. Delivery valve
7. Valve seat

VARIABLE SPEED CONTROL (SPRING ASSISTED CABLE OPERATED). To adjust low idle speed, move locknut (4–Fig. PE-8) and knurled nut (5) to end of control rod (6). Move control lever to idle speed position and loosen locknut (2). Turn cable adjuster (3) so control cable does not limit control rod movement. Loosen locknut (8) and turn adjuster (9) in to increase speed or out to decrease speed. Recommended idle speed is 1200 rpm. Secure knurled nut at end of rod with locknut.

NOTE: If minimum operating speed required is greater than idle speed setting, turn knurled nut towards the bracket until desired speed is obtained.

To adjust maximum engine speed setting, loosen locknut (11) and move control rod in direction of arrow until adjusting nut (10) is against the bracket (7). Turn adjusting nut clockwise to decrease speed or counterclockwise to increase speed. Maximum no-load speed should be set 8 percent higher than rated full-load speed specified on engine name plate.

Position plate (12) against nut (10) and tighten locknut (11). Turn cable adjuster (3) as required to adjust control cable so control lever is capable of moving speed control from idle to maximum speed position.

INJECTION PUMP TIMING

Injection pump static timing is adjusted using shim gaskets between pump body and mounting surface of crankcase. To check injection timing, proceed as follows: On fixed speed and two-speed AA1 and AB1 engines operating at speeds above 3000 rpm, move STOP/RUN lever towards STOP posi-

Table 1—Specified injection timing.

Engine	Speed	Rpm	Flywheel Degrees BTDC
AA1	Fixed Speed and Two Speed	Up to 2000	24
AA1	Fixed Speed and Two Speed	2201 to 3000	27
AA1	Fixed Speed and Two Speed	3001 to 3300	27
AA1	Fixed Speed and Two Speed	3301 to 3600	33
AA1	All Variable Speeds	--	33
AB1	Fixed Speed and Two Speed	Up to 2200	23
AB1	Fixed Speed and Two Speed	2201 to 2700	26
AB1	Fixed Speed and Two Speed	2701 to 3000	30
AB1	Fixed Speed and Two Speed	3001 to 3600	30
AB1	All Variable Speeds	--	30
AC1	Fixed Speed and Two Speed	Up to 2200	26
AC1	Fixed Speed and Two Speed	2201 to 2800	28
AC1	Fixed Speed and Two Speeds	2801 to 3300	30
AC1	Fixed Speed and Two Speed	3301 to 3600	33
AC1	All Variable Speeds	--	30
AC1Z	All Speeds, Fixed or Variable	--	*32
AC1Z	All Speeds, Fixed or Variable	--	**30
AC1ZS	All Speeds, Fixed or Variable	1000 to 1250	20
AC1ZS	All Speeds, Fixed or Variable	1251 to 1800	25
AC2	All Fixed Speeds	2201 to 2800	30
AC2	All Fixed Speeds	2801 to 3200	32
AC2	All Fixed Speeds	3201 to 3600	34
AC2	All Variable Speeds	--	32

*Up to engine number 14649.

**Engine number 14650 and after.

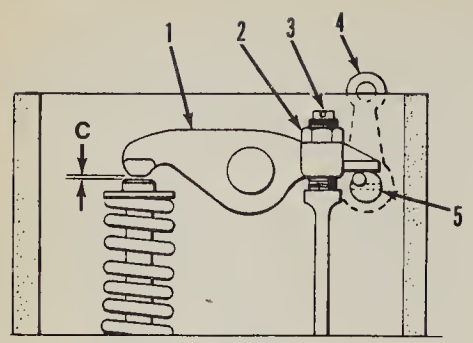


Fig. PE-11—Valve clearance (C) with engine cold should be 0.10 mm (0.004 inch).

1. Rocker arm
2. Locknut
3. Adjusting screw
4. Compression release lever
5. Spindle

tion to about 10 degrees before vertical position. On fixed speed and two-speed AA1 and AB1 engines operating at 3000 rpm and below, move STOP/RUN lever towards RUN position so lever is horizontal. On all fixed speed and two-speed AC1, AC1Z and AC1ZS engines, move STOP/RUN lever towards run position so lever is horizontal. On fixed speed and two-speed AC2 engines, position STOP/RUN lever midway between STOP and RUN positions. On all variable speed engines, move speed control lever to full speed position. Do not operate overload stop lever if so equipped. Shut off fuel supply. Remove injector high pressure fuel line. On AC2 engine, remove injector line for number 1 cylinder which is at gear end of engine. On all engines, remove the delivery union body (1–Fig. PE-9), spring guide (3), spring (5) and delivery valve (6) from injection pump. Do not remove the delivery valve seat (7). Reinstall the delivery union body and attach a spill pipe to delivery fitting. A spill pipe may be fabricated by cutting off an injector high pressure line. Turn on fuel supply and note that fuel should flow from spill pipe opening. If equipped with fuel transfer pump, priming lever must be operated. Turn flywheel by hand in normal direction of rotation so piston is on compression stroke. Stop turning crankshaft at point that fuel stops flowing from spill pipe. At this point beginning of injection occurs and specified timing mark on flywheel should be aligned with timing pointer on flywheel housing. Refer to Table 1 for specified injection timing.

To advance injection timing, reduce thickness of pump mounting shims. Increasing shim thickness will retard timing. A change in shim thickness of 0.1 mm (0.004 inch) will change timing about 1 degree.

When timing is correct, reinstall delivery valve assembly. Be sure "O" ring (2–Fig. PE-9) is properly positioned on the delivery union body, then tighten to 41 N·m (30 ft.-lbs.). Reinstall injector fuel line and bleed air from system as previously outlined.

REPAIRS

TIGHTENING TORQUES

Refer to the following table for special tightening torques.

Camshaft gear	36 N·m (27 ft.-lbs.)
Connecting rod	34 N·m (25 ft.-lbs.)
Crankshaft gear	36 N·m (27 ft.-lbs.)
Cylinder head	27 N·m (20 ft.-lbs.)
Flywheel	210 N·m (155 ft.-lbs.)
Injection pump	18 N·m (13 ft.-lbs.)
Injector	18 N·m (13 ft.-lbs.)
Oil pump	14 N·m (10 ft.-lbs.)
Timing gear cover	12 N·m (9 ft.-lbs.)

VALVE ADJUSTMENT

Valve clearance should be 0.10 mm (0.004 inch) for intake and exhaust with engine cold. To adjust clearance, remove rocker cover and rotate crankshaft until piston is at TDC on compression stroke. Loosen locknut (2–Fig. PE-11) and turn adjusting screw (3) until proper size feeler gage can be inserted between rocker arm and valve stem.

NOTE: Because of close confines of rocker box, an offset feeler gage should be used to obtain accurate adjustment.

COMPRESSION RELEASE

To adjust compression release mechnism, rotate crankshaft until piston is at TDC on compression stroke. With release lever (4–Fig. PE-11) in a vertical position, the spindle (5) should move the rocker arm just enough to take up the valve clearance. Use a screwdriver to rotate spindle if adjustment is required.

CYLINDER HEAD

To remove the cylinder head, remove the fuel tank and tank bracket (AC2 engine only). Remove muffler, air cleaner, manifolds and cylinder cowls. Remove injector high pressure pipe, fuel leak-off pipe and oil supply pipe from cylinder head. Remove rocker cover, priming plunger and injector assembly. Loosen cylinder head nuts gradually in sequence shown in Fig. PE-12. Remove

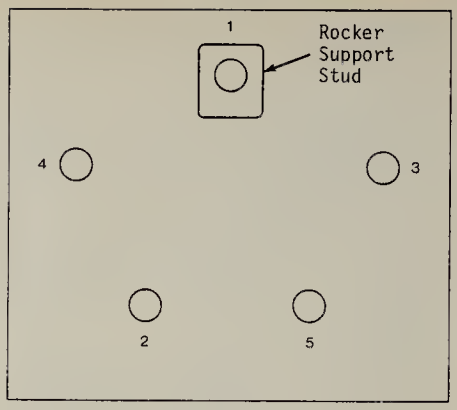


Fig. PE-12—Follow sequence shown when loosening or tightening cylinder head stud nuts. Refer to text.

rocker assembly and push rods. Note position of push rods so they can be reinstalled in their original positions. Lift off cylinder head.

When reinstalling cylinder head, always renew cylinder head gasket, rocker support seal and push rod tube seals. Be sure push rods are reinstalled in their original positions. On A2C engine, install manifold or use a straightedge to ensure cylinder heads are properly aligned. On all engines, tighten cylinder head stud nuts gradually one quarter of a turn at a time following sequence shown in Fig. PE-12. Final torque is 30 N·m (22 ft.-lbs.). After engine has run for 20 hours, nuts should be loosened (one at a time in sequence shown in Fig. PE-12) one quarter turn and retorqued to 30 N·m (22 ft.-lbs.).

VALVE SYSTEM

When removing valve components, be sure to identify all parts so they can be reinstalled in their original positions. Clean and inspect all parts for excessive wear or other damage. Valve guides and valve seat inserts are renewable.

When renewing valve guides, heat cylinder head in boiling water for about two minutes prior to removing and installing guides. Use a suitable tool to avoid damage to cylinder head or guides. Do not use excessive force. Heat cylinder head an additional two minutes if heavy resistance is encountered. Inside diameter of valve guides is prefinished and guide should not be reamed.

With valves temporarily installed in cylinder head, measure distance (D–Fig. PE-13) from surface of cylinder head to top of valve. If valve depth exceeds the following values, valve seat inserts must be renewed. On AA1 engines up to serial number 141926, valve depth should be 0.99-1.45 mm (0.039-0.057 inch) and maximum allowable depth is 1.65 mm (0.065 inch). On AA1 engines with serial number 141927 and onward,

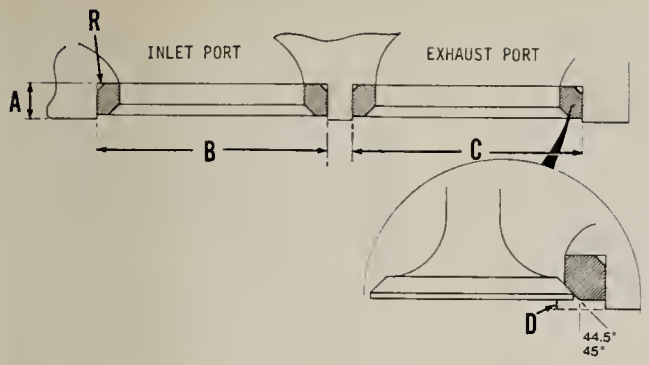


Fig. PE-13—Cross-sectional view of valve seat inserts and cylinder head counterbores. Refer to text for dimensions.
A. Counterbore depth
B. Counterbore width (intake)
C. Counterbore width (exhaust)
D. Depth from cylinder head surface
R. Radius

valve depth should be 0.63-1.06 mm (0.025-0.042 inch) and maximum allowable depth is 1.27 mm (0.050 inch). On all other engines, valve depth should be 1.29-1.72 mm (0.051-0.068 inch) and maximum allowable depth is 1.93 mm (0.076 inch).

To renew valve seat inserts, cylinder head counterbores must be machined to the dimensions listed in the following table. The letters refer to Fig. PE-13. Heat cylinder head to 150° C (300°F) prior to pressing in new guides.

AA1 Engine (Up to S.N. 24999)

A	4.74-4.80 mm (0.187-0.189 in.)
B	32.00-32.02 mm (1.260-1.261 in.)
C	28.82-28.85 mm (1.135-1.136 in.)
R	0.4 mm (0.016 in.)

AA1 Engine (S.N. 25000-141926) - AB1 Engine (Up to S.N. 29188)- AC1 Engine (Up to S.N. 6467)

A	4.19 mm (0.165-0.167 in.)
B	32.00-32.02 mm (1.260-1.261 in.)
C	32.00-32.02 mm (1.260-1.261 in.)
R	0.4 mm (0.016 in.)

AA1 Engine (S.N. 141927 onwards)- AB1 Engine (S.N. 29189 onwards)- AC1 Engine (S.N. 6468 onwards)- All AC1Z, AC1ZS and AC2 Engines

A	4.19-4.24 mm (0.165-0.167 in.)
B	32.00-32.02 mm (1.260-1.261 in.)
C	32.00-32.02 mm (1.260-1.261 in.)
R	0.4 mm (0.016 in.)

INJECTOR

REMOVE AND REINSTALL. Thoroughly clean injector and surrounding area prior to removing injector. Remove air cleaner, cylinder cowling and fuel tank if so equipped. Disconnect fuel return line and high pressure pipe and immediately plug all openings. Remove retaining nuts and withdraw injector.

Two different injector seal washers have been used. A copper seal washer (2–Fig. PE-14) is used on AA1 engines up to serial number 93723, on AB1 engines up to serial number 29188, on AC1 engines up to serial number 3866, on AC1Z engines up to serial number 149 and on AC1ZS engines beginning with serial number 632 through current production. A copper washer is also used on special build AA1 engines after serial number 93724 which operate at 1500 rpm or below on light load applications. The heat shield (3) is used only on AC1 engines prior to serial number 3866. A steel shield washer (5–Fig. PE-15) is used on all other engines. The steel washer must be installed with the dimple facing the injector. The washers are not interchangeable.

To reinstall injector, reverse the removal procedure using a new sealing washer. Tighten mounting nuts to 18 N·m (13 ft.-lbs.).

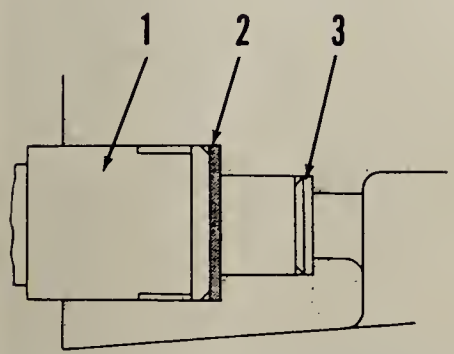


Fig. PE-14—A copper injector sealing washer is used on some engines. The heat shield is used only on early AC1 engines up to serial number 3866.
1. Injector body
2. Copper washer
3. Heat shield

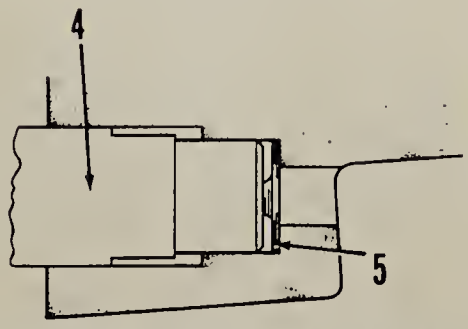


Fig. PE-15—Some engines use a steel shield washer (5) to seal injector (4) in cylinder head. Washer must be installed with dimple towards the injector.

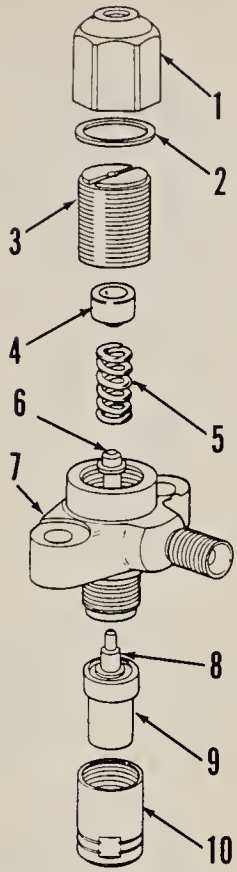


Fig. PE-16—Exploded view of injector assembly.
1. Cap nut
2. Gasket
3. Adjusting screw
4. Spring seat
5. Spring
6. Push rod
7. Body
8. Nozzle needle
9. Nozzle body
10. Nozzle nut

TESTING. A suitable test stand is required to check injector operation. Only clean, approved testing oil should be used to test injector. Injector should be checked for proper opening pressure, seat leakage, back leakage and spray pattern.

WARNING: Fuel leaves the injector nozzle with sufficient force to penetrate the skin. When testing, keep yourself clear of nozzle spray.

Attach injector to test pump and operate tester lever several strokes to purge air from nozzle and to make sure

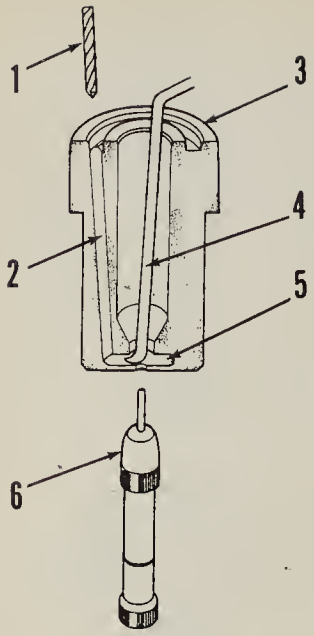


Fig. PE-17—Cross-sectional view of nozzle valve body showing areas to be cleaned.

1. Wire or twist drill
2. Fuel feed passage
3. Nozzle pressure face
4. Special scraper
5. Fuel chamber
6. Spray hole cleaner

nozzle valve is not stuck. Operate tester lever slowly and observe gage pressure reading. Nozzle opening pressure should be 16200-18300 kPa (2350-2650 psi). Opening pressure is adjusted by removing cap nut (1–Fig. PE-16) and turning adjusting screw (3).

To check seat leakage, wipe nozzle tip dry. Operate tester lever to maintain pressure at about 1000 kPa (150 psi) below opening pressure for a period of 10 seconds. If a drop forms at nozzle tip during this period, nozzle seat is not sealing and injector must be overhauled or renewed.

To check back leakage, raise tester pressure to 15200 kPa (2200 psi). Then, measure time required for pressure to drop to 10100 kPa (1470 psi). If time required is less than six seconds, nozzle is defective.

To check spray pattern, operate tester lever about six strokes in ten seconds. The nozzle should open with a chattering sound and spray should emerge in a straight axis from nozzle tip. Spray pattern should be even and well atomized. If pattern is ragged or intermittent, nozzle should be overhauled or renewed.

OVERHAUL. To disassemble injector, secure injector body (7–Fig. PE-16) in a vise or holding fixture. Remove nozzle nut (10) and withdraw nozzle valve assembly (8 and 9). Remove cap nut (1), adjusting screw (3), spring seat (4), spring (5) and push rod (6).

Thoroughly clean all parts in a suitable solvent. Use a brass wire brush to remove dirt and carbon from outer surfaces of injector. Do not use steel wire brush or sharp metal tools to clean injector components. Protect all polished surfaces from scratches or other damage. Clean fuel feed passage (2–Fig. PE-17) by inserting a suitable size wire (1) or twist drill. Use a special scraper (4) to clean fuel chamber (5). Use a cleaning wire (6) to clean nozzle spray hole. Be careful not to damage nozzle valve seat or pressure face areas of nozzle body. Make certain nozzle needle (8–Fig. PE-16) slides smoothly in bore of nozzle body (9). If needle sticks, reclean or renew nozzle valve assembly.

When reassembling injector, be sure all parts are clean and wet with diesel fuel as they are assembled. Recheck injector operation as outlined in TESTING section.

INJECTION PUMP

Injection pump type is identified by the pump code on the pump name plate. Bryce "B" series, Bryce "E" series and I.E.S.A. injection pumps have been used on these engines. It is recommended that injection pump be tested and repaired only by a shop qualified in diesel fuel injection repair.

To remove injection pump, shut off fuel supply and remove fuel tank if so equipped. Remove air cowling. Disconnect fuel lines and immediately plug all openings. Remove pump mounting nuts. Align fuel pump rack with notch in crankcase, then withdraw pump. Retain mounting shims for reassembly.

To reinstall injection pump, rotate crankshaft so injection cam lobe on camshaft is pointing away from injection pump. Install pump with shim pack on crankcase making sure pump control rack engages governor lever fork. Tighten retaining nuts to 18 N·m (13 ft.-lbs.). Complete installation by reversing the removal procedure. Bleed fuel system and check injection timing as previously outlined.

PISTON, PIN, RINGS AND CYLINDER

The piston may be removed after removing the cylinder head and cylinder barrel. Remove piston pin retaining ring, push out piston pin and separate piston from connecting rod. Be sure to retain shims installed between cylinder and crankcase as they control clearance between top of piston and cylinder head.

Check cylinder bore for out-of-round, excessive wear or other damage. Cylinder standard inner diameter is 69.850-69.875 mm (2.750-2.751 inches) for AA1 engine and 76.20-76.23 mm (3.000-3.001 inches) for all other

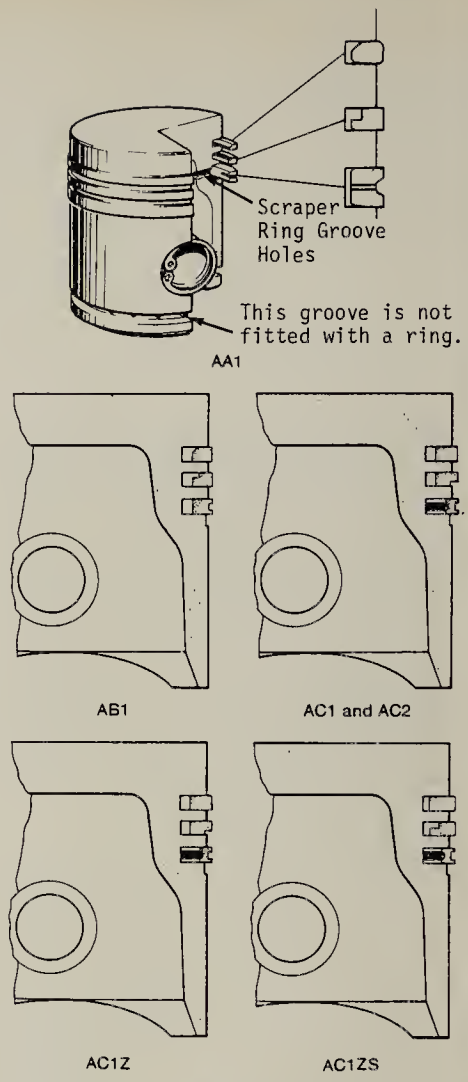


Fig. PE-18—Cross-sectional view of pistons and rings. Note ring shape and position for correct installation.

engines. If cylinder bore wear exceeds 0.25 mm (0.010 inch), cylinder may be rebored and honed for installation of oversize pistons and rings. Pistons are available in oversizes of 0.508 mm (0.020 inch) and 1.016 mm (0.040 inch).

Piston ring end gap should be measured with ring positioned squarely in cylinder. Refer to the following table for ring end gap specifications.

AA1 Engine

End gap–all rings

Desired	0.28-0.41 mm (0.011-0.016 in.)
Maximum	1.14 mm (0.045 in.)

AB1 Engine

End gap–all rings

Desired	0.30-0.43 mm (0.012-0.017 in.)
Maximum	1.14 mm (0.045 in.)

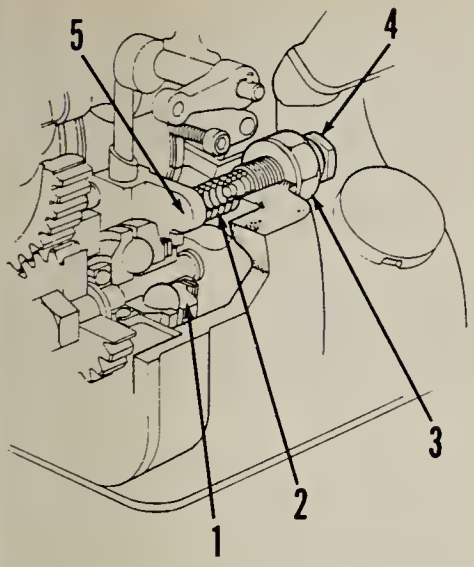


Fig. PE-19—Cross-sectional view of typical governor assembly.

1. Flyball governor
2. Governor spring
3. Locknut
4. Adjuster
5. Governor bracket

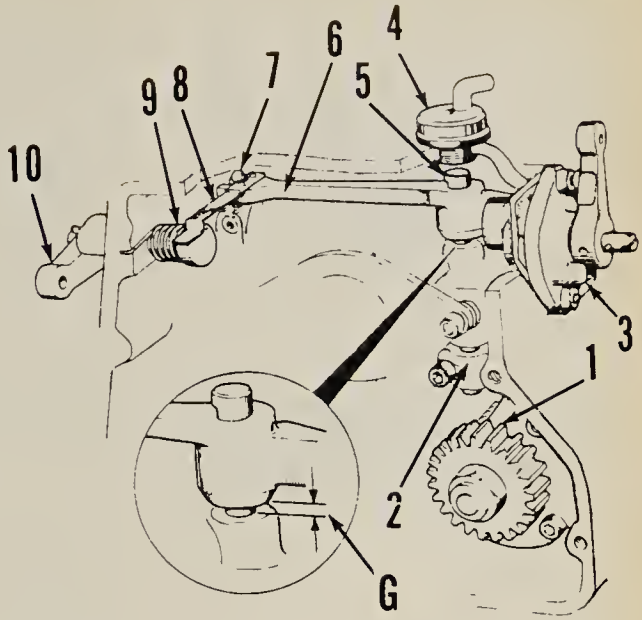


Fig. PE-20—View of typical governor linkage. Clearance (G) between operating arm (6) and governor shaft bushing should be 0.25 mm (0.010 inch). Overload stop (10) is not used on all engines.

1. Governor gear
2. Governor bracket
3. STOP/RUN lever assy.
4. Breather assy.
5. Operating shaft
6. Operating lever
7. Pump control rack
8. Governor leaf spring
9. Return spring
10. Overload stop lever

AC1, AC1Z, AC1ZS and AC2 Engines

End gap – Compression rings

Desired	0.30-0.43 mm (0.012-0.017 in.)
Maximum	1.14 mm (0.045 in.)

End gap – oil control ring

Desired	0.23-0.36 mm (0.009-0.014 in.)
Maximum	1.14 mm (0.045 in.)

To check piston ring groove wear, insert new rings in piston grooves and measure clearance between top of ring and top of groove with a feeler gage. If side clearance exceeds 0.25 mm (0.010 inch) for any ring, renew piston.

When reinstalling rings onto piston, refer to appropriate drawing in Fig. PE-18 for correct installation of rings. Note that some pistons used in AA1 engines may have a ring groove machined below the piston pin, but a ring is not installed in this groove.

Before reinstalling piston on connecting rod, heat piston in hot water to make piston pin installation easier. Stagger ring end gaps around the piston making sure none of the gaps are in line with piston pin bore. Lubricate piston and cylinder with oil, then assemble cylinder with shims onto crankcase. If connecting rod was removed with the piston, be sure numbers on rod and cap are on the same side and face toward camshaft side of engine.

Check piston-to-cylinder head clearance as follows: Place three pieces of soft wire or solder on top of piston making sure they will not be aligned with valve heads. Install cylinder head and tighten stud nuts to specified torque. Rotate crankshaft by hand so piston goes past TDC. Remove cylinder head and measure thickness of the flattened wires. Average thickness should be 0.56-0.66 mm (0.022-0.026 inch). To adjust clearance, add or remove shims between bottom of cylinder and crankcase as necessary.

After renewing piston rings, manufacturer recommends the following procedure to properly seat the rings. Operate for 2 minutes with no-load, then run for 10 minutes at half-load, and finally run for a minimum of 8 hours continuous at full-load.

CONNECTING ROD

Connecting rod may be removed after first removing cylinder head, oil pan and rod cap. Heating piston in hot water will make removal and installation of piston pin easier.

The connecting rod small end is fitted with a renewable bushing. When installing a new bushing, be sure oil hole in bushing is aligned with hole in connecting rod. Inside diameter of bushing when installed should be 22.233-22.243 mm (0.8753-0.8757 inch).

A precision, insert type bearing is used in big end of connecting rod. Desired rod bearing clearance is 0.025-0.090 mm (0.0010-0.0035 inch). Bearings are available in undersizes of 0.25 mm (0.010 inch) and 0.50 mm (0.020 inch).

CAMSHAFT

To remove the camshaft, remove mounted fuel tank (if so equipped) and oil pan. Remove rocker cover, rocker arm support, rocker arms and push rods. Disconnect fuel lines and remove injection pump and fuel feed pump (if so equipped). Remove engine gear cover. Remove cap screws securing the camshaft thrust plate. Note that early AC1Z (before serial number 2000) and AC1ZS (before serial number 10000) engines do not use a thrust plate. On these engines, camshaft end play is controlled by inner face of the gear cover. On all engines, move cam followers away from the camshaft, then withdraw camshaft from the engine. Remove cam followers noting their positions for reassembly. Camshaft gear is a press fit on camshaft.

Inspect cam followers, cam lobes, journals and crankcase bearing bores for wear or other damage. Renew if necessary. If camshaft gear was removed, heat gear before reinstalling onto shaft. Tighten gear retaining cap screw to 36 N·m (27 ft.-lbs.).

Lubricate all parts with clean oil during reassembly. Check camshaft end play with a dial indicator. Desired end play is 0.08-0.25 mm (0.003-0.010 inch). Be sure timing marks on camshaft gear and crankshaft gear are aligned. Complete installation by reversing the removal procedure.

GOVERNOR

R&R AND OVERHAUL. The flyball type governor is driven by the camshaft gear. The governor assembly may be removed after removing the engine gear cover. Inspect bearings, balls and sliding cone. Renew governor assembly if parts are worn or damaged.

To remove governor linkage, the camshaft gear and governor assembly must be removed. Remove governor spring adjuster (4 – Fig. PE-19) and governor spring (2). Remove STOP/RUN lever

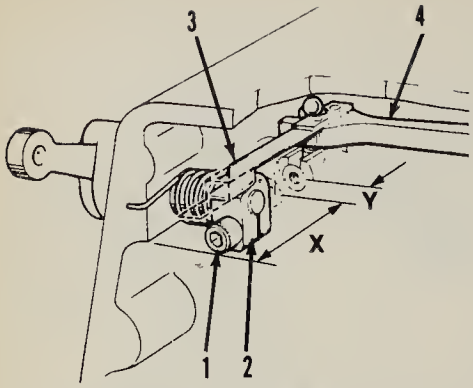


Fig. PE-21—To adjust early style overload stop. Measure distance "X" between end of pump control rack and face of crankcase. Add "Y", 11.2 mm (0.441 inch) for AA1 and AB1 engines or 12.7 mm (0.500 inch) for AC1, to "X" measurement and refer to text.

1. Clamp screw
2. Stop cam
3. Governor leaf spring
4. Governor operating lever

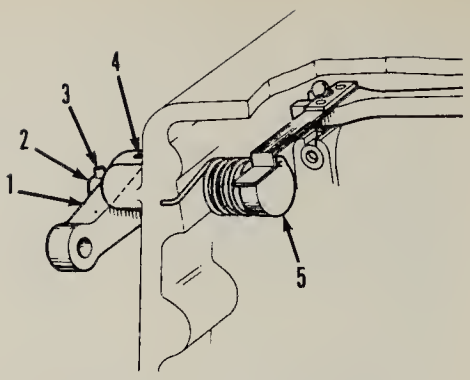


Fig. PE-22—View of later style overload stop. Refer to text for initial adjustment.

1. Lever
2. Spindle
3. Pin
4. Hole
5. Cam

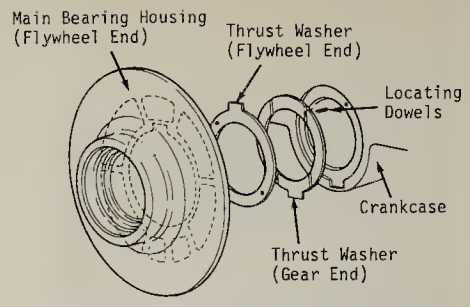


Fig. PE-23—When installing crankshaft thrust washers, be sure they are properly positioned on locating dowels and grooved side is facing the crankshaft.

assembly (3—Fig. PE-20). Remove governor lever bracket (2). Remove breather assembly (4) or plug from top of crankcase. Raise the operating shaft (5) and position a block of wood at the bottom of the shaft. Use a tubular drift over the top of operating lever (6) and shaft to drive the lever downward on shaft. Gradually increase thickness of wood block until shaft is clear of the lever. The overload stop (10), if so equipped, is set at the factory and should not be removed unless oil is leaking around shaft or return spring is broken.

To reinstall the governor assembly and linkage, reverse the removal procedure. To adjust governor linkage, move variable speed or two-speed control to maximum speed position. Loosen governor bracket mounting screw. Push the operating lever (6) inward to maximum fuel position. Adjust clearance (G) between operating lever and top governor shaft bushing to 0.25 mm (0.010 inch) and tighten governor bracket cap screw. Adjust overload stop (if so equipped) as outlined in the following paragraph.

To adjust early style overload stop, move STOP/RUN lever to STOP position and measure distance (X—Fig. PE-21) between end of injection pump rack and front face of crankcase. Move STOP/RUN lever to RUN position. On AA1 and AB1 engines, add 11.2 mm (0.441 inch) to measurement (X) and on AC1 engine, add 12.7 mm (0.500 inch) to measurement (X). On all engines, move governor operating lever (4) until end of pump rack is positioned at the calculated distance. While holding rack in this position, loosen cam clamp screw (1) and rotate stop cam (2) until it just touches the step of governor leaf spring (3). Retighten the clamp screw.

To adjust later style overload stop, turn the spindle (2—Fig. PE-22) until pin (3) is aligned with hole (4) in the lever (1).

To check the overload stop setting, engine must be at normal operating temperature. Accelerate the engine from idle to full speed with no load applied and observe exhaust smoke. When stop setting is correct, exhaust should be a barely visible haze. If black exhaust smoke is emitted, turn overload stop spindle clockwise a small amount at a time until desired smoke level is obtained.

Refer to MAINTENANCE section for engine speed adjustment procedure.

OIL PUMP AND RELIEF VALVE

The rotary type engine oil pump is mounted at the gear end of crankcase and is driven by the camshaft. Engine oil pan and gear cover must be removed for access to the oil pump. Remove the oil pump gear, then remove pump mounting cap screws and withdraw pump assembly.

Remove pump backplate (if so equipped) from pump body. Inspect rotors and pump body for excessive wear or other damage and renew pump assembly if necessary. Rotor end clearance should be 0.025-0.064 mm (0.001-0.0025 inch) with a wear limit of 0.127 mm (0.005 inch). Rotor shaft diameter should be 15.032-15.044 mm (0.5918-0.5923 inch). Clearance between shaft and pump body bore should be 0.038-0.076 mm (0.0015-0.0030 inch) with a wear limit of 0.127 mm (0.005 inch).

When reassembling pump, chamfered edge of outer rotor should be towards pump body. Align notch in backplate (if so equipped) with notch in pump body. Tighten pump mounting screws to 14 N·m (10 ft.-lbs.).

With engine at normal temperature and operating speed, oil pressure should be at least 240 kPa (35 psi) on all engines except AC1ZS rated at 1250 rpm. On this engine, minimum allowable oil pressure is 206 kPa (30 psi). A ball type pressure relief valve is located in the side of the crankcase next to the oil pump. The valve is set at the factory and should not require adjustment. If valve is removed, count the number of turns required to remove the adjusting screw so it can be reinstalled in it original position.

CRANKSHAFT AND BEARINGS

To remove the crankshaft, remove cylinder head, oil pan, connecting rod, cylinder and piston. Remove flywheel using a suitable puller. Remove crankshaft extension shaft and gear cover. Remove crankshaft gear using a suitable puller. On AC2 engine, remove two cap screws securing center main bearing housing. On all engines, remove main bearing housing from flywheel end. Withdraw crankshaft out flywheel end of crankcase.

Inspect crankpins, main journals and main bearings for excessive wear or other damage. Crankpin and main journal standard diameters are both 41.262-41.275 mm (1.6245-1.6250 inches). If journals are out-of-round in excess of 0.063 mm (0.0025 inch), crankshaft should be reground to 0.254 mm (0.010 inch) or 0.508 mm (0.020 inch) undersize. Be sure oil passages in crankshaft are clean before reinstalling.

Precision, sleeve type main bearings are pressed into the gear end of crankcase and the bearing retainer housing at flywheel end. Suitable tools should be used when removing and installing bearings. The crankcase and bearing housing should be heated before pressing bearings in or out. To ease installation, new bearings should also be cooled in a freezer before installation. Be sure oil holes in bearing and crankcase housing are aligned. New bearings are prefinished for proper fit and no further machining is required. Desired main bearing clearance for all engines except AC2 engine is 0.033-0.076 mm (0.0013-0.0030 inch). Main bearing clearance for AC2 engine

should be 0.05-0.088 mm (0.0021-0.0036 inch) for gear end bearing, 0.04-0.078 mm (0.0016-0.0031 inch) for flywheel end bearing and 0.093-0.137 mm (0.0037-0.0054 inch) for center bearing.

A precision, insert type connecting rod bearing is used on all engines. Desired rod bearing clearance is 0.025-0.090 mm (0.0010-0.0035 inch).

Crankshaft end thrust is taken by two thrust washers located at either end of crankshaft. Recommended crankshaft end play is 0.076-0.609 mm (0.003-0.024 inch).

To reinstall crankshaft, proceed as follows: Before installing the flywheel end oil seal, the seal lip cavity should be filled with lithium base grease or soak seal in engine oil for 24 hours prior to reassembly. Install seal so face of seal is flush with outer face of bearing retainer. Install gear end thrust washer (Fig. PE-23) making sure grooved side is facing the crankshaft and locating dowels are in place. Insert crankshaft into crankcase. On AC2 engine, install top half of intermediate bearing making sure the oil passage cross hole is towards flywheel end of engine. Align matching identification numbers and install bottom half of bearing. Tighten cap screws to 41 N·m (30 ft.-lbs.). On all engines, install flywheel end thrust washer into bearing housing making sure grooved side is facing away from housing. Install bearing housing assembly and tighten cap screws evenly in a diagonal pattern. Heat the crankshaft gear before driving it onto the crankshaft. Tighten the retaining cap screw to 36 N·m (27 ft.-lbs.). Be sure to align timing marks on camshaft gear and crankshaft gear. Complete installation by reversing the removal procedure. Tighten flywheel retaining nut to 210 N·m (155 ft.-lbs.) and gear cover cap screws to 12 N·m (9 ft.-lbs.).

PETTER

Model	No. Cyls.	Bore	Stroke	Displ.
PH1	1	87.3 mm (3.437 in.)	100 mm (3.937 in.)	659 cc (40.2 cu.in.)
PH2	2	87.3 mm (3.427 in.)	100 mm (3.937 in.)	1318 cc (80.4 cu. in.)
PJ1, PJ1Z	1	96.8 mm (3.812 in.)	110 mm (4.33 in.)	810 cc (49.4 cu. in.)
PJ2, PJ2Z	2	96.8 mm (3.812 in.)	110 mm (4.33 in.)	1620 cc (98.9 cu. in.)
PJ3	3	96.8 mm (3.812 in.)	110 mm (4.33 in.)	2430 cc (148.2 cu. in.)

All engines are four-stroke, air-cooled direct injection diesels. Standard crankshaft rotation is clockwise at flywheel end. Firing order is 1-3-2 for PJ3 engine.

MAINTENANCE

LUBRICATION

Recommended engine oil is SAE 10W for temperatures below 5°C (41°F), SAE 20W-20 for temperatures between 5°C (41°F) and 30°C (86°F) and SAE30 for temperatures above 30°C (86°F). SAE 10W-30, 10W-40, 15W-40 and 20W-40 multigrade oils are also approved for use in all temperatures. All oil must be heavy duty diesel oil which meets MIL-L-46152-B specification.

NOTE: Use of oil meeting API specification CD or MIL-L-2104C specification is not recommended in new or overhauled engines until after the running-in period and first oil change, or in engines running at light load in low ambient temperatures. Oil meeting CD and MIL-L-2104C specifications should be used only in engines operating at high loads, speeds and ambient temperatures.

Manufacturer recommends renewing oil and oil filter (if so equipped) after the first 20 hours of operation on a new or overhauled engine. Thereafter, oil and oil filter should be renewed at intervals of 250 operating hours. Refer to the following table for approximate crankcase refill capacities.

Crankcase Capacity

PH1	2.84 liters (5 pints)
With filter	3.41 liters (6 pints)
PH2	5.68 liters (10 pints)
With filter	6.53 liters (11.5 pints)
PJ1	3.4 liters (6 pints)
PJ1Z	2.85 liters (5 pints)
PJ2	6.53 liters (11.5 pints)
PJ2Z	5.7 liters (10 pints)
PJ3	7.67 liters (13.5 pints)

FUEL SYSTEM

FUEL FILTER. Manufacturer recommends renewing fuel filter element after every 500 hours of operation or sooner if loss of power is evident. Do not attempt to clean filter element. After renewing fuel filter, air must be bled from fuel system as outlined in the following paragraph.

BLEED FUEL SYSTEM. To bleed fuel system, first loosen the two bleed screws (1–Fig. PE-30) on top of fuel filter. When air-free fuel flows from the vents, retighten the screws. Loosen bleed screw (2) on fuel pump and actuate fuel feed pump lever (3), if so equipped, until fuel flows from vent, then retighten screw. Loosen the high pressure fuel line connection at the injector. With pump control in "RUN" position, crank engine until fuel is discharged at the loosened connection. Retighten injector line fitting and start engine.

ENGINE SPEED ADJUSTMENT

FIXED SPEED CONTROL. On fixed speed engines, the action of the centrifugal governor is balanced by the speeder spring (4–Fig. PE-31). The

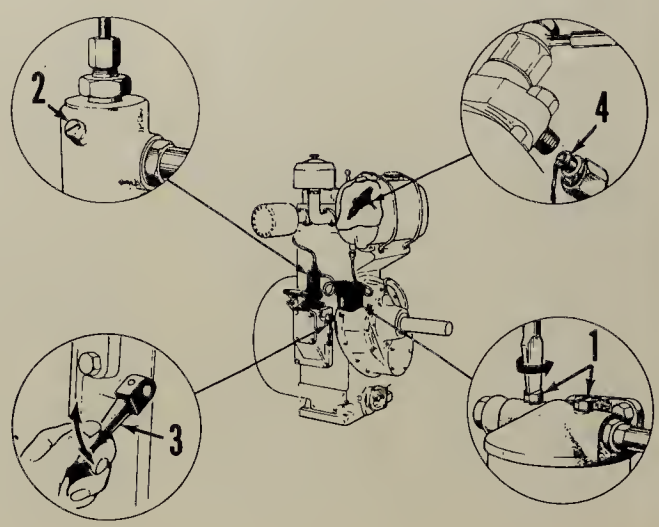


Fig. PE-30—Fuel system air venting points. Refer to text for procedure.

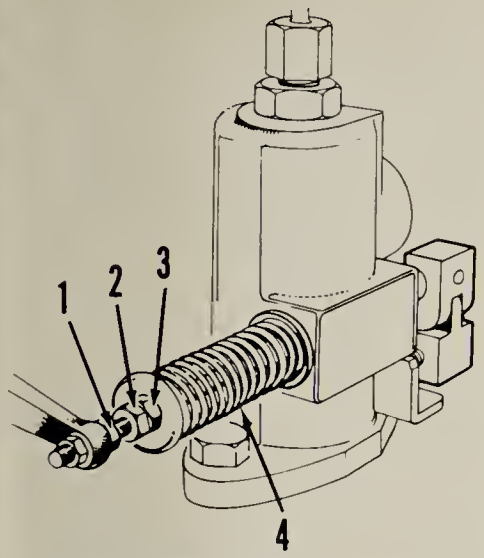


Fig. PE-31—Speeder spring (4) balances governor forces to regulate engine speed. Refer to text for adjustment.

1. Adjusting screw
2. Locknut
3. Nut
4. Speeder spring

spring is adjustable to allow small variation in a set speed range. If a speed outside this range is desired, a different spring and governor may be required.

To adjust fixed speed control, loosen locknut (2) and adjust nut (3) against the spring (4) to increase speed or away from spring to decrease speed. Maximum speed with no load should be set at 4.5 percent above rate full-load speed indicated on engine name plate.

VARIABLE FIXED SPEED (EARLY TYPE). To adjust engine speed, loosen locknut (1–Fig. PE-32). To decrease speed setting turn nuts (2 and 3) towards the flywheel until desired speed is obtained. To increase speed, turn nuts away from flywheel. Tighten nuts against bracket (4) to secure speed adjustment.

VARIABLE SPEED CONTROL. To adjust low idle speed, loosen locknuts (1–Fig. PE-33) and turn adjusting

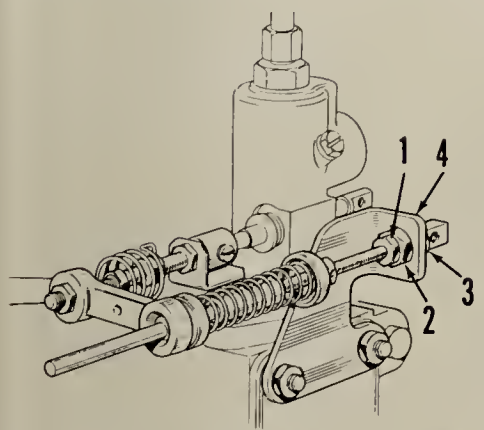


Fig. PE-32—View of early type adjustable fixed speed control.

1. Locknut
2. Nut
3. Nut
4. Bracket

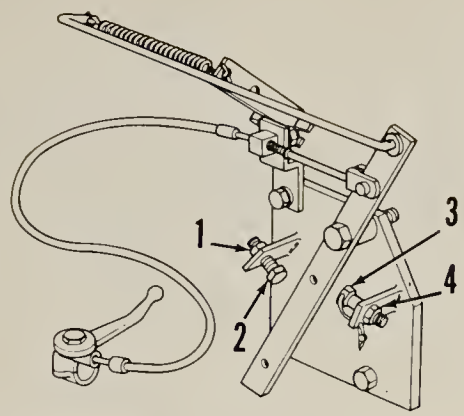


Fig. PE-33—View of variable speed control linkage adjustment points. Refer to text.

1. Locknut
2. Idle adjusting screw
3. Maximum speed adjusting screw
4. Locknut

screw (2) clockwise to decrease speed or counterclockwise to increase speed. Recommended idle speed is 950 to 1000 rpm.

To adjust maximum no-load speed, loosen locknut (4) and move control lever to full speed position. Turn adjusting screw (3) clockwise to increase speed or counterclockwise to decrease speed. Maximum speed with no load should be set at 8 percent higher than specified rated full-load speed indicated on engine name plate.

VARIABLE SPEED CONTROL (EARLY TYPE). To adjust low idle speed, loosen locknut (5–Fig. PE-34) and turn adjusting screw (6) clockwise to increase speed or counterclockwise to decrease speed. Recommended idle speed is 500 to 600 rpm.

To adjust maximum no-load speed, loosen locknut (4) and move control lever to full speed position. Turn adjusting screw (3) clockwise to decrease speed or counterclockwise to increase speed setting. Maximum no-load speed

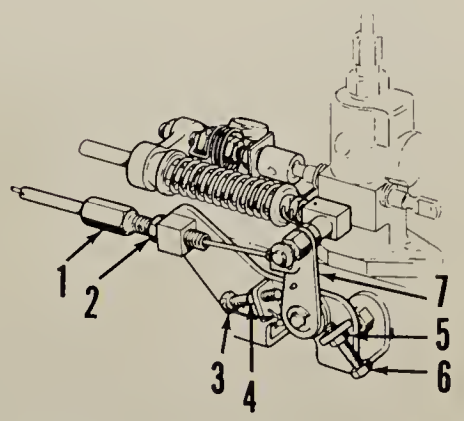


Fig. PE-34—View of early type variable speed control adjustment points. Refer to text.

1. Cable adjuster
2. Locknut
3. Maximum speed adjusting screw
4. Locknut
5. Locknut
6. Idle speed adjusting screw
7. Control arm

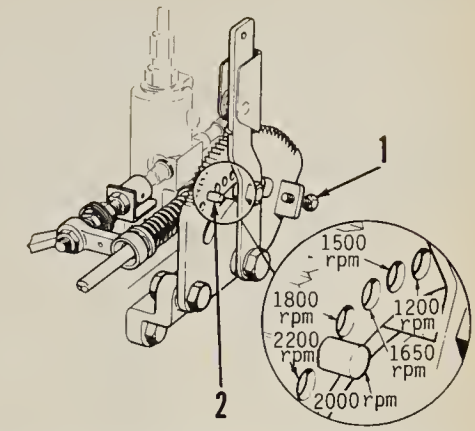


Fig. PE-35—View of ratchet type variable speed control. Maximum speed stop is adjusted by inserting dowel (2) in appropriate hole as shown in inset.

1. Idle speed adjusting screw
2. Dowel

should be set 8 percent above specified full-load speed indicated on engine name plate.

Be sure control cable allows full travel of control arm so it contacts both adjusting screws. If necessary, turn cable adjuster (1) until there is a small amount of slack in inner cable. Control lever should be able to move slightly before inner cable begins to move the control.

VARIABLE SPEED (RACHET TYPE). To adjust idle speed, turn adjusting screw (1–Fig. PE-35) clockwise to increase speed or counterclockwise to decrease speed. Recommended idle speed is 500 to 600 rpm.

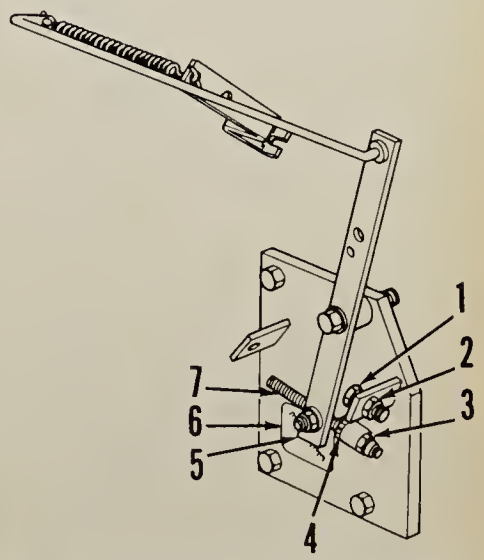
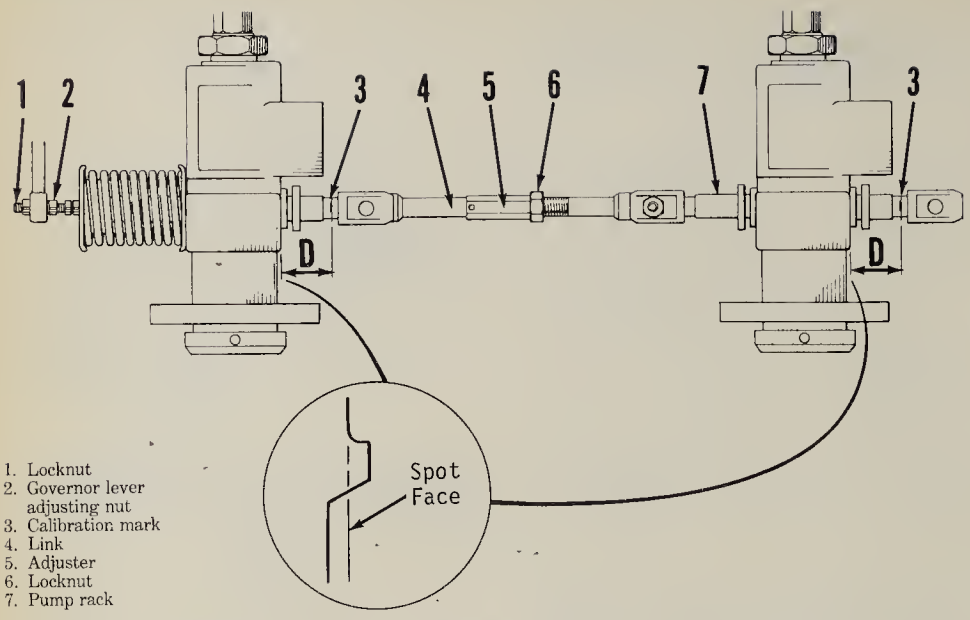


Fig. PE-36—Adjustable fixed speed control is used on some engines. Refer to text for adjustment procedure.

1. Maximum speed stop screw
2. Locknut
3. Locknut
4. Locknut
5. Control lever
6. Speed scale
7. Adjusting screw



1. Locknut
2. Governor lever adjusting nut
3. Calibration mark
4. Link
5. Adjuster
6. Locknut
7. Pump rack

Fig. PE-37—On multiple cylinder engines, a separate injection pump is used for each cylinder. Pump timing and pump rack setting for each pump must be sychronized for proper engine operation. Refer to text.

To set maximum full-speed stop, move dowel (2) to appropriate hole in rachet bracket as indicated in inset.

ADJUSTABLE FIXED SPEED. To set the maximum no-load speed, loosen locknuts (2, 3 and 4 – Fig. PE-36). Turn the adjusting screw (7) in conjunction with the stop screw (1) until speed setting is 8 percent higher than the rated full-load speed indicated on the engine name plate. At this point, the bottom end of the lever (5) should point to the appropriate rated rpm graduation on the speed scale (6). If not, it will be necessary to adjust speeder spring tension and the adjusting rod until desired speed setting and graduation alignment on scale is obtained.

INJECTION PUMP TIMING

To time fuel injection pump, the following procedure must be followed.

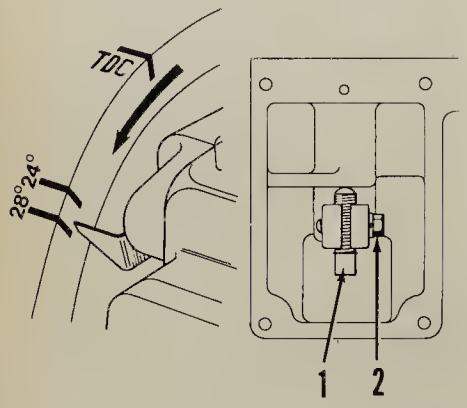


Fig. PE-38—Injection pump timing is adjusted by turning rocker adjuster screw (1). Refer to text for specified injection timing.

On multiple cylinder engines, the injection pump for each cylinder must be set one at a time. Remove the fuel pump cover. Position injection pump rack so calibration mark (3 – Fig. PE-37) is 20.6 mm (13/16 inch), setting distance "D", from spot face on pump body. Remove injector high pressure pipe from pump being timed. Remove the discharge fitting (1 – Fig. PE-39), spring and delivery valve (4) from pump, then reinstall discharge fitting. Do not remove the delivery valve seat (5). Attach a spill pipe to pump discharge fitting. Note that fuel will flow from the spill pipe and a suitable container should be used to catch the fuel. Turn the flywheel until appropriate piston is on compression stroke and specified timing mark on flywheel is aligned with pointer. Refer to pump injection timing table. Loosen pump rocker clamp bolt (2 – Fig. PE-38) and unscrew adjusting screw (1) until pump is at bottom of its stroke. With fuel flowing from pump discharge fitting (fuel feed pump, if so equipped, must be operated), turn adjusting screw until fuel flow just stops. Beginning of injection occurs at this point. Tighten clamp bolt being careful not to disturb adjusting screw setting. Remove spill pipe and discharge fitting. Reinstall delivery valve and spring and tighten discharge fitting to 54 N·m (40 ft.-lbs.). Repeat adjustment procedure for the other injection pump(s) on multiple cylinder engines.

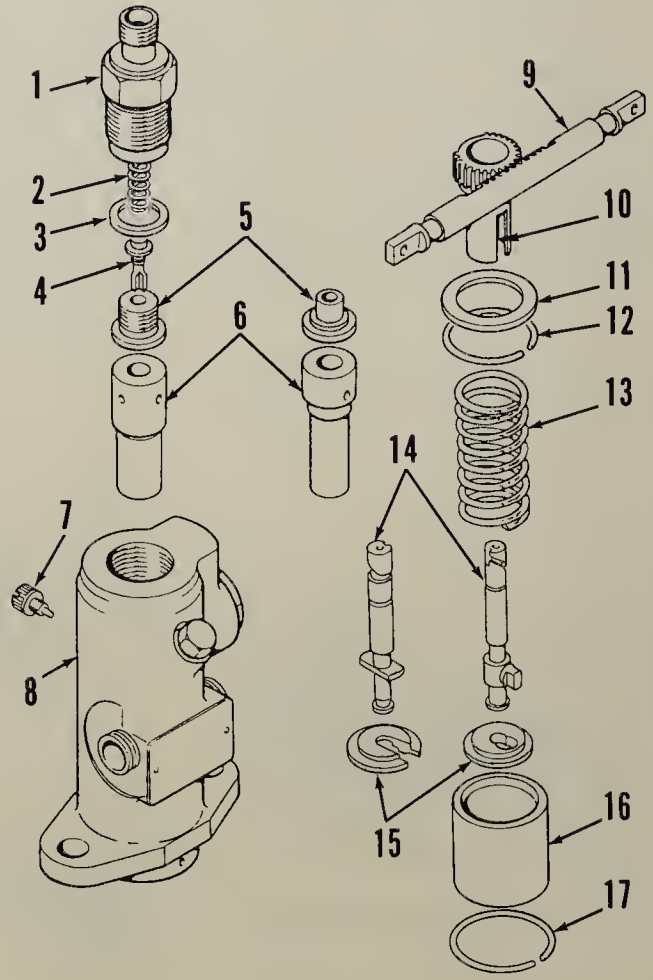


Fig. PE-39—Exploded view of injection pump assembly. A Bryce or CAV pump may be used. Both pumps are similar.

1. Discharge fitting
2. Spring
3. Gasket
4. Delivery valve
5. Delivery valve seat
6. Pumping element
7. Locating screw
8. Pump body
9. Rack
10. Pinion
11. Spring plate
12. Retaining ring (Bryce)
13. Spring
14. Plunger
15. Spring retainer
16. Tappet
17. Retaining ring

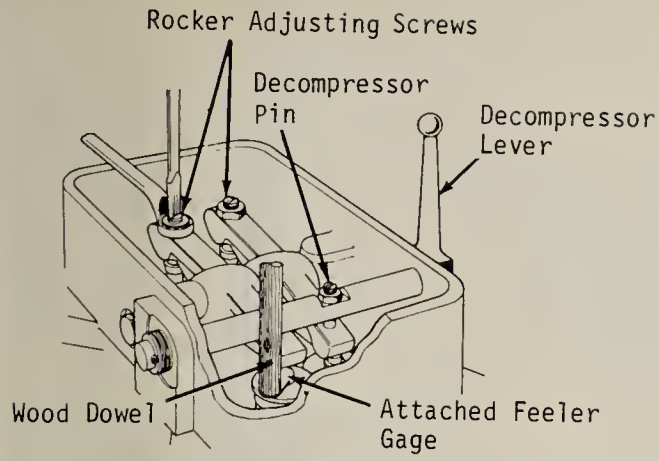


Fig. PE-40—Valve rocker clearance should be adjusted to 0.10 mm (0.004 inch) for both intake and exhaust. A special tool, fabricated from a wood dowel with a feeler gage attached as shown, will make measuring clearance easier on PH1 and PH2 engines.

Injection timing (BTDC)
PH1 and PH2 engines
Up to 1650 rpm .....24°
1650 to 2200 rpm.....28°
PJ Engines
Fixed speed up to 1650 rpm.....23°
1651 to 2000 rpm.....26°
Variable and two speed.....23°
PJZ Engines
All speeds.....23°

REPAIRS

TIGHTENING TORQUES

Refer to the following table for special tightening torques.

Connecting rod.....77 N·m (57 ft.-lbs.)
Crankshaft gear.....62 N·m (46 ft.-lbs)
Cylinder crankcase studs.....34-41 N·m (25-30 ft.-lbs.)
Cylinder head.....75-88 N·m (55-65 ft.-lbs.)
Fuel injector.....20 N·m (15 ft.-lbs.)
Inspection cover.....22 N·m (16 ft.-lbs.)

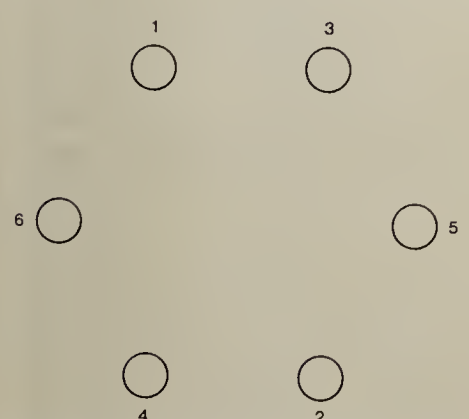


Fig. PE-41—Follow sequence shown when loosening or tightening cylinder head stud nuts.

VALVE ADJUSTMENT

Valve rocker clearance with engine cold should be 0.10 mm (0.004 inch) for intake and exhaust valves. Manufacturer recommends checking valve clearance and adjusting, if necessary, after every 250 hours of operation.

To adjust valve clearance, rotate crankshaft until piston is at top dead center on compression stroke (both valves closed). Loosen rocker adjusting screw locknut (Fig. PE-40) and turn adjusting screw until a 0.10 mm (0.004 inch) feeler gage can be inserted between valve stem end and rocker arm.

NOTE: Due to close confines of rocker box of PH1 and PH2 engines, an offset feeler gage or a fabricated tool as shown in Fig. PE-40 should be used to obtain accurate measurements.

Repeat adjustment procedure for each cylinder on multiple cylinder engines.

COMPRESSION RELEASE

To adjust compression release, first rotate crankshaft so piston is at TDC on compression stroke. Move decompressor lever (Fig. PE-40) to vertical position. Adjust decompressor pin until it contacts the exhaust rocker, then turn pin clockwise an additional ½ turn on PH1 and PH2 engines or an additional ⅔ turn on PH series engines. Make certain the valve is not depressed more than 0.63 mm (0.025 inch) or valve may hit the piston causing serious damage.

CYLINDER HEAD

A separate cylinder head is used for each cylinder on multiple cylinder engines. To remove a cylinder head proceed as follows: Remove cylinder air cowling. Remove intake and exhaust manifolds. Remove injector fuel lines and the oil supply pipe to the rockers. Plug all openings to prevent entry of dirt. Remove the fuel injector. Remove

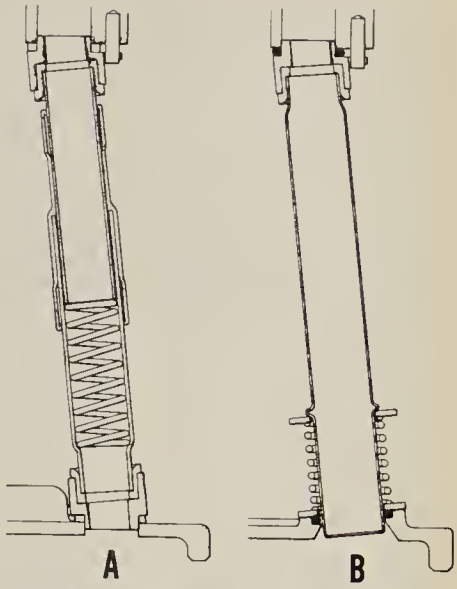


Fig. PE-42—View showing correct installation of early style (A) push rod tube assembly and late style (B) push rod tube assembly.

the rocker box and rocker assembly. Remove push rods, noting their position for reassembly, and push rod tubes. Gradually loosen cylinder head nuts in sequence shown in Fig. PE-41, then lift off cylinder head assembly.

When reinstalling cylinder head, always renew cylinder head gasket. On multiple cylinder engine, use a straightedge or attach manifold to heads to align manifold mounting surfaces. Tighten cylinder head nuts a quarter of a turn at a time following sequence shown in Fig. PE-41 until specified torque of 75.88 N·m (55-65 ft.-lbs.) is obtained. Install push rod tubes and adapters as shown in Fig. PE-42. Be sure push rods are reinstalled in their original positions. Push rods should not be interchanged. Complete installation by reversing the removal procedure. After engine has operated for about 20 hours, allow engine to cool, then retorque cylinder head nuts to specified torque following sequence shown in Fig. PE-41.

VALVE SYSTEM

As valve components are removed, identify all parts so they can be reinstalled in their original positions. Clean all parts and inspect for excessive wear or other damage.

Valve face and seat angles are 45° for intake and exhaust. Desired valve seating width is 1.33-1.47 mm (0.052-0.057 inch). With valves installed in cylinder head, distance (R–Fig. PE-43) from surface of cylinder head to valve head should be 0.81-1.17 mm (0.032-0.046 inch) on PH engines or 0.68-1.09 mm (0.027-0.043 inch) on PJ engines. If valves are recessed excessively, cylinder

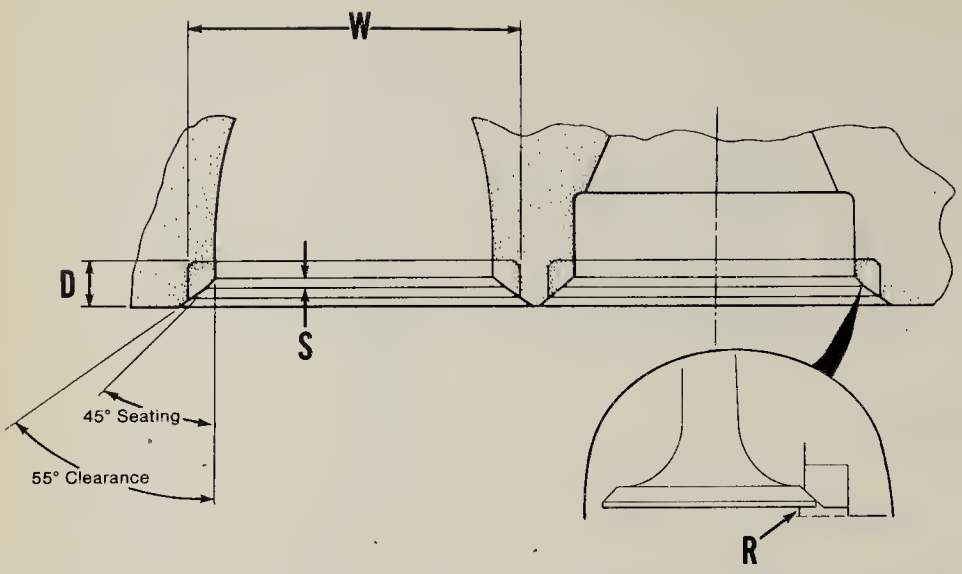


Fig. PE-43—Cylinder head ports must be machined as shown to install valve seat inserts. Refer to text for required dimensions.

head should be machined for installation of valve seat inserts. Refer to Fig. PE-43 and the following table for cylinder head dimensions required for installation of seat inserts.

PH1-PH2 Engines

Depth (D)	6.019-6.045 mm (0.237-0.238 in.)
Width (W)	35.687-35.712 mm (1.405-1.406 in.)
Valve seat (S)	1.33-1.47 mm (0.052-0.057 in.)

PJ1-PJ1Z-PJ2-PJ2Z-PJ3 Engines

Depth (D)	6.019-6.045 mm (0.237-0.238 in.)
Width (W)	42.16-42.18 mm (1.661-1.662 in.)
Valve seat (S)	1.33-1.47 mm (0.052-0.057 in.)

INJECTOR

REMOVE AND REINSTALL. Thoroughly clean injector, fuel lines and surrounding area prior to removing injector. Disconnect the pressure pipe and fuel leak-off pipe from the injector and immediately plug all openings to prevent entry of dirt. Remove retaining nuts and withdraw injector.

To reinstall injector, reverse the removal procedure. Tighten high pressure pipe union nuts finger tight, then tighten an additional third of a turn. Tighten injector retaining nuts to 20 N·m (15 ft.-lbs.).

TESTING. A suitable test stand is required to check injector operation. Only clean, approved testing oil should be used to test injector. Injector should be checked for proper opening pressure, seat leakage and spray pattern.

WARNING: Fuel leaves the injector nozzle with sufficient force to penetrate the skin. When testing, keep yourself clear of nozzle spray.

Attach injector to test pump and operate tester lever several strokes to purge air from nozzle and to make sure nozzle valve is not stuck. Operate tester lever slowly and observe gage pressure reading. On PH1 and PH2 engines that operate below 1100 rpm, opening pressure should be 13750-15200 kPa (1995-2205 psi). On all other engines, opening pressure should be 19700-21700 kPa (2850-3150 psi). Nozzle opening pressure is adjusted by removing the cap nut (1–Fig. PE-44) and turning adjusting screw (3).

To check nozzle seat leakage, wipe nozzle tip dry. Operate tester lever to maintain pressure at about 1000 kPa (150 psi) below opening pressure for a period of 10 seconds. If a drop forms at nozzle tip during this period, nozzle seat is not sealing and injector should be overhauled or renewed.

To check spray pattern, operate tester lever about six strokes in 10 seconds. The nozzle should open with a sharp chattering sound. The spray from each nozzle hole should be well atomized and free from ragged edges or solid squirts of fuel.

OVERHAUL. To disassemble injector, secure injector body (6–Fig. PE-44) in a vise or holding fixture. Remove nozzle nut (10) and withdraw nozzle valve assembly (8 and 9). Remove cap nut (1), adjusting screw (3), spring (4) and spindle (5). If disassembling more than one injector, be sure to keep parts from each injector separated in a compartmented pan. Parts must not be interchanged.

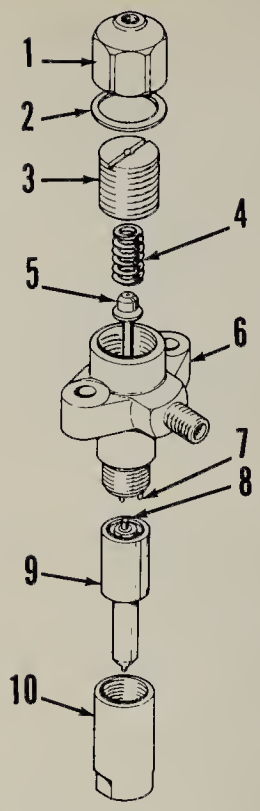


Fig. PE-44—Exploded view of fuel injector assembly.

1. Cap nut
2. Gasket
3. Adjusting screw
4. Spring
5. Spring seat & spindle
6. Body
7. Dowels
8. Nozzle needle
9. Nozzle body
10. Nozzle nut

Thoroughly clean all parts in a suitable solvent. Use a brass wire brush to remove dirt and carbon from outer surfaces of injector. Do not use steel wire brush, emery cloth or sharp metal tools to clean injector components. Protect all polished surfaces from scratches or other damage. The sealing surfaces between nozzle valve (9) and body (6) must be clean and smooth. Clean the fuel feed hole (2–Fig. PE-45) by inserting a suitable wire or twist drill (1). Use a special

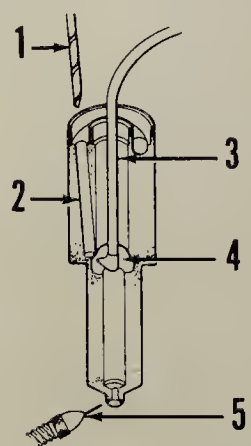


Fig. PE-45—Cross-sectional view of nozzle valve body showing areas to be cleaned during injector overhaul.

1. Twist drill
2. Fuel feed passage
3. Special scraper
4. Fuel chamber
5. Spray hole cleaner

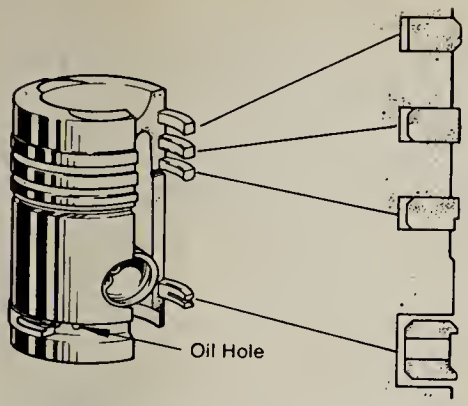


Fig. PE-47—Cross-sectional view showing correct installation of piston rings for PH1 and PH2 engines.

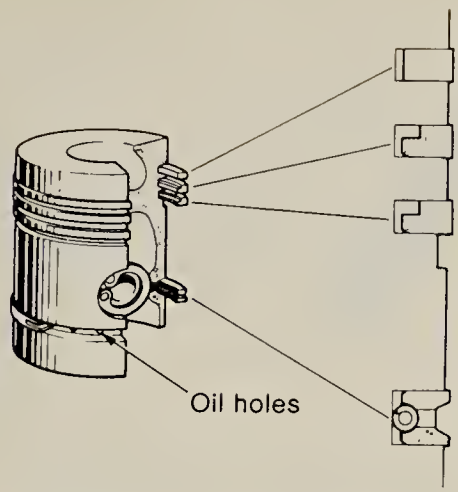


Fig. PE-48—Cross-sectional view showing correct installation of piston rings for PJ1, PJ1Z, PJ2, PJ2Z and PJ3 engines.

scraper (3) to clean deposits from nozzle fuel chamber (4). Clean the nozzle spray holes by inserting a cleaning wire (5) of slightly smaller diameter than the spray hole. Inspect nozzle needle for dull or very bright patches or any discoloration indicating overheating. When wet with diesel fuel, the needle must slide smoothly in bore of nozzle body. If needle sticks, reclean or renew nozzle valve assembly.

When reassembling injector, be sure all parts are clean and wet with diesel fuel as they are assembled. Recheck injector operation as outlined in TESTING section.

INJECTION PUMP

All engines are equipped with a Bryce or CAV fuel injection pump. Refer to Fig. PE-39 for an exploded view of injection pump. On multiple cylinder engines, a separate injection pump is used for each cylinder. The injection pump(s) is driven by a rocker arm which is actuated by the camshaft. It is recommended that injection pump be tested and repaired only by a shop qualified in diesel fuel injection repair.

REMOVE AND REINSTALL. Shut off fuel supply, then disconnect fuel inlet pipe and injector high pressure pipe from the pump. Plug all openings to prevent entry of dirt. On variable speed engines, remove the spring between governor fulcrum arm and pump rack extension of pump at flywheel end of engine. Disconnect pump linkage on multiple cylinder engines. Remove pump mounting cap screws and lift pump from the engine.

To reinstall pump, first rotate crankshaft to position pump rocker arm at the bottom of its stroke. Assemble pump to the mounting bracket and note that special screw with the extended plain shank is installed in right-hand position. Complete installation by reversing the removal procedure. Bleed air from fuel system. On multiple cylinder engines, adjust connecting linkage as outlined in the following paragraph. Check and adjust pump timing as previously outlined.

LINKAGE ADJUSTMENT. On multiple cylinder engines, adjust linkage beginning at the flywheel end pump as follows: Push pump rack towards the flywheel and hold against governor fulcrum arm adjusting screw (maximum fuel position). If equipped with overload stop, the hinged lower part of stop must be raised to allow full movement of rack Measure distance from calibration mark (3–Fig. PE-37) to spot face on side of pump (not the rack bushing). Distance (D) should be 12.7 mm (0.5 inch). If necessary, loosen locknut (1) and adjust governor lever screw (2) to obtain specified dimension. A special setting gage (number 392645) is available from the manufacturer for use in making this adjustment. The calibration mark on remaining pump(s) must also be 12.7 mm (0.5 inch) from spot face on pump body. To adjust, loosen locknut (6) and turn adjuster (5) to obtain correct rack setting.

PISTON, PIN, RINGS AND CYLINDER

To remove cylinder and piston with connecting rod, remove cylinder head and crankcase inspection cover. If equipped with straight connecting rod bearing cap (Fig. PE-49), remove injection pump(s) together with pump mounting bracket. Remove connecting rod bearing cap. Mark the cylinder and crankcase so cylinder can be reinstalled in it original position. Lift cylinder, piston and connecting rod as an assembly from crankcase. Retain shims used between cylinder and crankcase for use in reassembly. Withdraw piston from cylinder. If piston pin is difficult to remove, heat piston in hot water for a few minutes until pin can be pushed out.

Check cylinder bore for out-of-round, excessive wear or other damage. Cylinder standard inner diameter is 87.465-87.491 mm (3.4435-3.4445 inches) for PH1 and PH2 engines. On all other engines, standard cylinder bore is 96.965-96.990 mm (3.8175-3.8185 inches). If bore wear exceeds 0.25 mm (0.010 inch), cylinder may be rebored and honed for installation of oversize piston and rings. Pistons are available in oversizes of 0.508 mm (0.020 inch) and 1.016 mm (0.040 inch).

Piston ring end gap should be measured with piston ring positioned squarely in cylinder. On PH1 and PH2 engines, desired ring end gap is 0.74-0.94 mm (0.029-0.037 inch). On all other engines, desired ring end gap is 0.69-0.89 mm (0.027-0.035 inch) and maximum allowable end gap is 1.52 mm (0.060 inch).

To check piston ring groove wear, insert new rings into piston grooves and measure clearance between top of ring and top of groove with a feeler gage. Desired side clearance for compression rings is 0.08-0.13 mm (0.0033-0.0053 inch). Side clearance for oil scraper ring should be 0.06-0.11 mm (0.0025-0.0045 inch). Maximum side clearance for all rings is 0.25 mm (0.010 inch).

If piston is being reused, make certain oil drain holes in bottom ring groove are clean. When assembling rings onto piston, note shape of rings and refer to appropriate Fig. PE-47 or PE-48 for correct installation of rings. Stagger ring end gaps evenly around piston making sure they are not in line with piston pin bore.

To make piston pin installation easier, piston should be heated in hot water for a few minutes before assembly. If piston has valve recesses in the piston crown, be sure they are toward camshaft side of engine. Install original shim pack between bottom of cylinder and crankcase. Be sure assembly numbers on connecting rod and rod bearing cap match and are on the same side. If equipped with an offset rod bearing cap, be sure cap retaining bolt heads face away from injection pump side of engine. Tighten connecting rod cap screws to 77 N·m (57 ft.-lbs.).

If the cylinder, piston or connecting rod was renewed, or if original shim pack is not being used, check and adjust piston-to-cylinder head clearance as follows: Place three pieces of soft wire or solder on top of piston making sure they will not be aligned with valve heads. Install cylinder head and tighten stud nuts to specified torque. Rotate crankshaft by hand so piston goes past

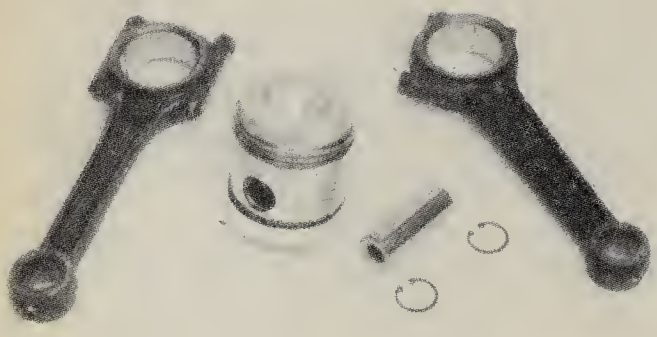


Fig. PE-49—Engines may be equipped with connecting rod using a straight bearing cap or an offset cap.

top dead center. Remove cylinder head and measure thickness of the flattened wires. Average thickness should be 0.91-1.017 mm (0.036-0.042 inch). If necessary to adjust, add or remove shims between bottom of cylinder and crankcase.

Complete installation by reversing the removal procedure. After renewing piston rings, manufacturer recommends the following procedure to properly seat the rings. Operate engine for 2 minutes with no-load, then run for 10 minutes at half-load, and finally run for a minimum of 8 hours continuous at full-load.

CONNECTING ROD

Engines may be equipped with connecting rod having an offset bearing cap or a straight type bearing cap as shown in Fig. PE-49. The small end of connecting rod is fitted with a renewable bushing while the big end uses precision, thin wall, insert type bearing shells.

Inner diameter of small end bushing should be 30.035-30.048 mm (1.1825-1.1830 inches) for all engines. When renewing bushing, be sure hole in bushing is aligned with hole in the connecting rod.

Recommended connecting rod large end bearing operating clearance is 0.051-0.089 mm (0.002-0.0035 inch). No attempt should be made to modify bearing or connecting rod to obtain recommended clearance. Undersize bearings are available for service.

When reinstalling connecting rod, heat piston in hot water until piston pin will slide in freely. Be sure piston is positioned so valve recesses (if used) in piston crown are toward camshaft side of engine. If offset type connecting rod cap is used, cap retaining bolt heads should face away from camshaft side of engine. Make certain identification numbers on rod and cap match and are on the same side. Tighten rod cap bolts to 77 N·m (57 ft.-lbs.).

CAMSHAFT

To remove the camshaft, remove the gear cover and fuel pump bracket assembly. Remove rocker box, push rods and push rod tubes. Note position of push rods as they should not be interchanged when reassembling. Use rubber bands or other suitable devices to hold cam followers up away from camshaft and to prevent them from falling when camshaft is removed. If equipped with an SAE 5 bellhousing, the crankshaft gear and oil thrower must be removed. On PH1, PH2, PJ1Z and PJ2Z engines, a camshaft thrust plate (4—Fig. PE-50 is located between camshaft gear and crankcase. Thrust plate retaining screws (5) are accessible through holes in camshaft gear. Loosen screws and thrust plate will drop to end of slotted holes so camshaft can be removed. On all engines, withdraw camshaft and governor assembly from crankcase. If necessary, cam followers may be removed after camshaft is removed.

Inspect camshaft and gear for excessive wear or other damage. Check crankcase bearing bores for wear. A renewable bushing is used at gear end of crankcase. The camshaft journal at flywheel end operates directly in the crankcase bore. Camshaft and gear must be renewed as an assembly as gear is a shrink fit on the shaft and cannot be removed without damaging the gear or the camshaft. If equipped with a camshaft extension shaft, inspect support bearing and oil seal and renew if necessary. Heating extension shaft bearing in boiling water for about five minutes will make removal and installation of bearing easier. Be sure oil hole in housing is clean and is aligned with hole in bearing when pressing in a new bearing. Use suitable installing tool to avoid damaging bearing.

When reinstalling camshaft, lubricate bearing surfaces before inserting into crankcase. On PJ1, PJ2 and PJ3 engines, be sure thrust washers (3 and 6—Fig. PE-51) are held in proper position by pins (4). Make certain grooved side of inner washer is against thrust face of camshaft and the tang is located in plate recess. On PH1, PH2, PJ1Z and PJ2Z engines, install thrust plate (4—Fig. PE-50), if removed, and tighten retaining screws finger tight. On all engines, insert camshaft assembly aligning timing marks on camshaft gear and crankshaft gear. On PH1, PH2, PJ1Z and PJ2Z engines, raise thrust plate so upper edge engages groove in camshaft, then tighten retaining screws. Check camshaft end play by inserting a feeler gage between gear and thrust plate. Desired end play is 0.10-0.38 mm (0.004-0.015 inch). Renew thrust plate if

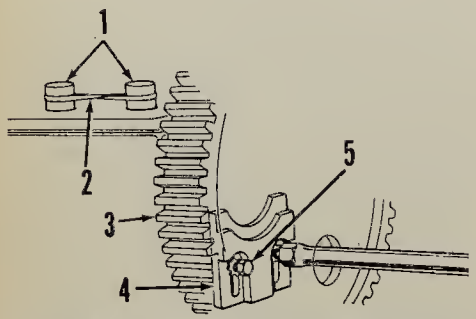


Fig. PE-50—A thrust plate (4) is located between camshaft gear and crankcase on PH1, PH2, PJ1Z and PJ2Z engines. A rubber band (2) may be used to support cam followers (1) when camshaft is removed.

1. Cam followers
2. Rubber band
3. Camshaft gear
4. Thrust plate
5. Retaining screws

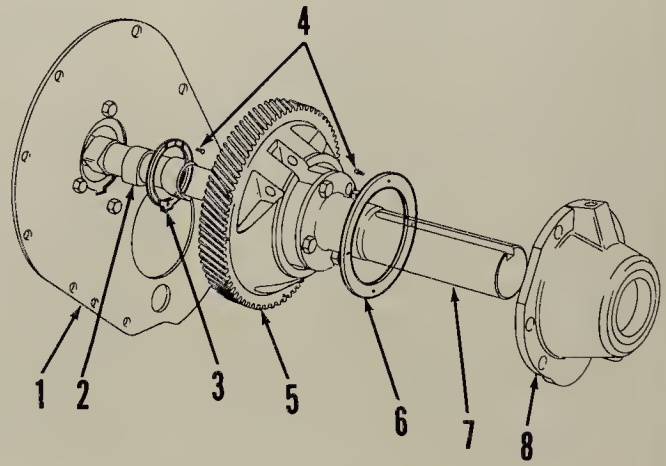


Fig. PE-51—Thrust washers (3 and 6) control end thrust of camshaft on PJ1, PJ2 and PJ3 engines. Some engines are equipped with camshaft extension shaft (7).

1. Plate
2. Camshaft
3. Thrust washer
4. Locating pins
5. Camshaft gear
6. Thrust washer
7. Extension shaft
8. Housing

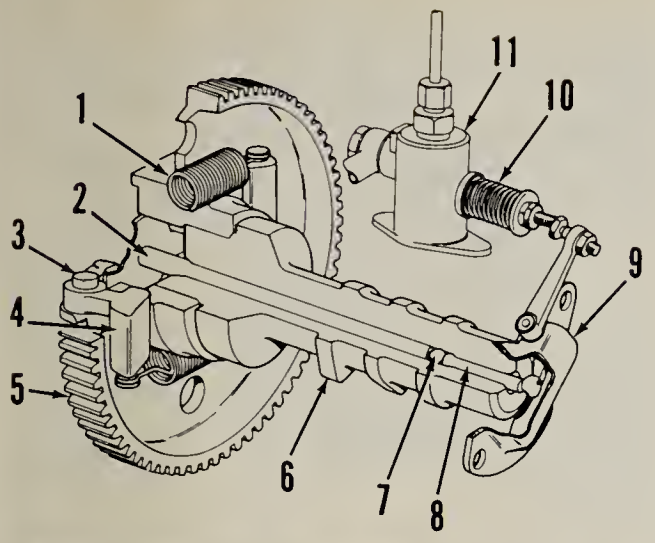


Fig. PE-52—Governor assembly is mounted on the camshaft gear.

1. Governor weight spring
2. Push rod
3. Pin
4. Governor weight
5. Camshaft gear
6. Camshaft
7. Steel ball
8. Push rod
9. Fulcrum arm
10. Speeder spring
11. Injection pump

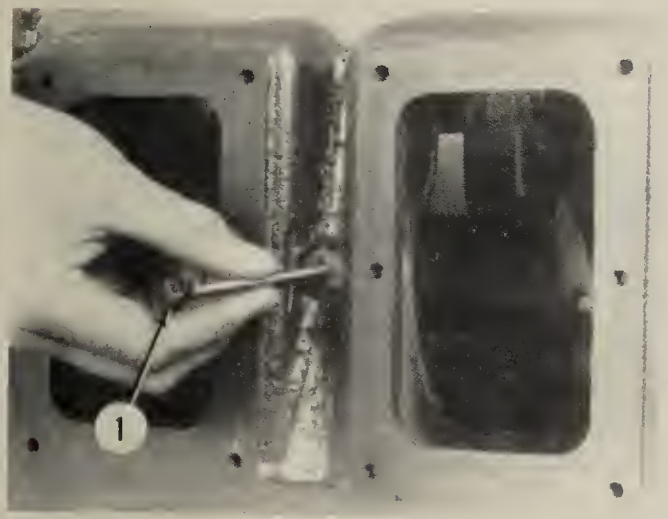


Fig. PE-53—On multiple cylinder engines, a locating screw (1) is used to position intermediate bearing housing in crankcase.

end play is excessive. On PJ1, PJ2 and PJ3 engines, install gear cover and extension shaft housing (if so equipped). Mount dial indicator on fuel pump side of crankcase with pointer against the side of one of the cam lobes. Desired end play is 0.13-0.71 mm (0.005-0.028 inch). Renew thrust washers if end play is excessive.

GOVERNOR

The governor assembly is mounted on the camshaft gear. Refer to CAMSHAFT section for removal procedure.

All components must move freely for proper governor operation. Remove governor push rods (2 and 8–Fig. PE-52) and steel ball (7). Be sure push rod hole through the camshaft is clean. Inspect for excessive wear and renew parts if necessary.

Refer to MAINTENANCE section for engine speed adjustment procedure.

CRANKSHAFT AND MAIN BEARINGS

To remove crankshaft, first remove cylinder head, cylinder, piston and connecting rod. Remove flywheel and gear end cover. Remove crankshaft gear using a suitable puller. On multiple cylinder engines, remove intermediate main bearing housing locating screw (1–Fig. PE-53). On all engines, mark crankshaft balance weights to identify assembly positions, then remove weights. Remove main bearing housing from flywheel end. Withdraw crankshaft through opening at flywheel end.

Inspect crankshaft and bearings for excessive wear or other damage. Oil pump drive gear is a shrink fit on crankshaft and should not be removed unless renewal is necessary. Heat the new gear prior to installation. Be sure thrust face of gear faces outward.

On PH1, PJ2, PJ1Z and PJ2Z engines, standard crankpin or intermediate main journal (if applicable) diameter is 60.312-60.325 mm (2.3745-2.3750 inches). Standard main journal diameter at gear end or flywheel end is 60.274-60.287 mm (2.3730-32.3735 inches). Desired rod bearing clearance is 0.051-0.089 mm (0.002-0.0035 inch). Main bearing clearance should be 0.051-0.114 mm (0.002-0.0045 inch).

On PJ1, PJ2 and PJ3 engines, standard diameter of crankpin or intermediate main journal (if applicable) is 60.312-60.325 mm (2.3745-2.3750 inches). Standard diameter of main journal at gear end is 60.274-60.287 mm (2.3730-2.3735 inches) while journal diameter at flywheel end is 104.661-104.673 mm (4.1205-4.1210 inches). Desired rod bearing clearance is 0.051-0.089 mm (0.002-0.0035 inch). Main bearing diametral clearance should be 0.051-0.115 mm (0.002-0.0045 inch) for gear end bearing, 0.080-0.135 mm (0.0028-0.0052 inch) for flywheel end bearing and 0.064-0.102 mm (0.0025-0.0040 inch) for intermediate bearing (if applicable).

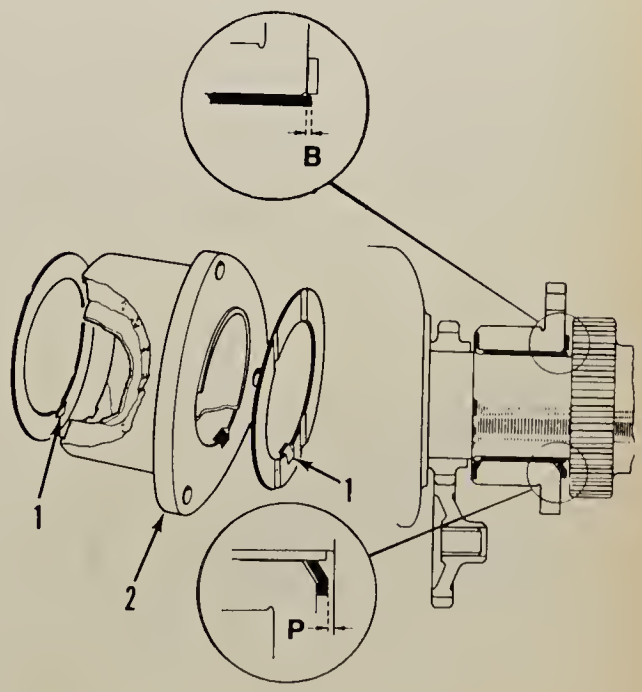


Fig. PE-54—Main bearing at gear end must protrude (B) beyond front surface of bearing housing (2) 1.27-1.52 mm (0.050-0.060 inch). Thrust washers (1) control crankshaft end play (P).

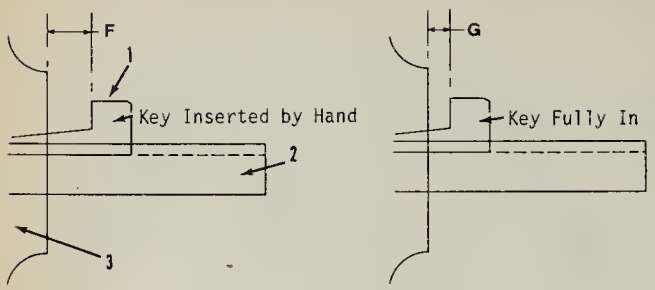


Fig. PE-55—On PH1, PH2, PJ1Z and PJ2Z engines, flywheel key (1) must be installed to dimensions shown. Refer to text.
F. 23.8 mm (15/16 in.)
G. 11.1 mm (7/16 in.)
1. Key
2. Crankshaft
3. Flywheel

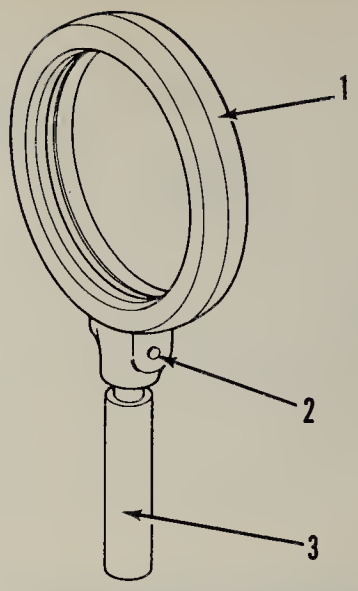


Fig. PE-57—Whenever oil pump is being serviced, plunger pin (2) connecting oil plunger (3) to crankshaft strap (1) should be renewed.

The main bearings are precision, thin wall, sleeve type bearings. Bearings are presized for proper fit and do not require further machining. Use suitable tools to remove and install bearings. Be sure bearing oil holes are aligned. The main bearing at gear end of crankcase must protrude between 1.27-1.52 mm (0.05-0.006 inch) beyond front surface of bearing housing as shown in (B–Fig. PE-54). Main and rod bearings are available in undersizes of 0.254, 0.508, 0.762 and 1.016 mm (0.010, 0.020, 0.030 and 0.040 inch) as well as standard size.

To reinstall crankshaft, proceed as follows: Install gear end bearing housing making sure oil hole is aligned with oil hole in crankcase. Install thrust washer (1–Fig. PE-54) making sure locating tangs are in bearing housing (2) notches and grooved side of washers face away from bearing housing. Use grease to hold washers in position. On two-cylinder engines, assemble intermediate main bearing housing with side marked TOP towards flywheel end. Tighten bearing housing nuts to 34 N·m (25 ft.-lbs.). On three-cylinder engines, be sure intermediate bearing housings are correctly installed with oil hole and locating screw hole in proper positions. Tighten bearing housing cap screws to 54 N·m (40 ft.-lbs.). On all engines, be sure all bearing surfaces are well lubricated, then carefully insert crankshaft into crankcase. Install a new oil seal in flywheel end bearing housing making sure seal face is flush with rear face of bearing housing. Lubricate seal lip, then reinstall bearing housing. Tighten retaining cap screws evenly. Install intermediate bearing housing locating screw (if applicable). Assemble balance weights in their original positions. On PH2 engine, tighten balance weight retaining bolts to 267 N·m (197 ft.-lbs.). On all other engines, tighten balance weight retaining bolts to 160 N·m (118 ft.-lbs.). Heat crankshaft gear before reinstalling. Brace opposite end of crankshaft with a wood block while driving gear onto crankshaft. Do not attempt to insert a wedge between crankshaft and crankcase during this operation as serious damage to crankcase or crankshaft could result. Be sure timing marks on teeth of crankshaft gear and camshaft gear are aligned. Make certain thrust washers are still in proper position after gear is installed. Tighten gear retaining cap screw to 62 N·m (46 ft.-lbs.). Crankshaft end play should be 0.2-0.5 mm (0.008-0.020 inch) and maximum allowable end play is 0.63 mm (0.025 inch). Complete installation by reversing the removal procedure.

FLYWHEEL

PH1-PH2-PJ1Z-PJ2Z Engines

REMOVE AND REINSTALL. To remove flywheel, first remove key using a tapered key drift or special key extractor tool available from manufacturer. Clean exposed portion of crankshaft, then withdraw flywheel.

To reinstall flywheel, lubricate crankshaft surface with small amount of oil. Push flywheel onto shaft making sure flywheel is bottomed against shoulder of crankshaft. A new key must be used when reinstalling flywheel and should be installed as follows: File a chamfer on all four corners of key to prevent key from binding in keyway. Insert key by hand as far as possible. At this point, distance (F-Fig. PE-55) between flywheel boss and head of key should be 23.8 mm (15/16 inch). If distance is greater, withdraw key and remove metal from bottom of key to obtain recommended measurement.

NOTE: Do not remove metal from tapered surface of key.

Install key and drive into flywheel until measurement (G) between flywheel and head of key is 11.1 mm (7/16 inch).

PJ1-PJ2-PJ3 Engines

REMOVE AND REINSTALL. The flywheel is located on crankshaft with dowels and retained by cap screws. Two studs should be used in place of two diagonally opposite retaining screws to act as guides and support weight of flywheel as it is being removed and reinstalled. Flywheel retaining cap screws should be tightened gradually in diagonal pattern to 43 N·m (32 ft.-lbs.) on PJ1 and PJ2 engines or 64 N·m (47 ft.-lbs.) on PJ3 engine.

OIL PUMP AND RELIEF VALVE

A plunger type oil pump was used on early production PH1 engines. The pump is mounted at the gear end of the engine and actuated by an eccentric on the crankshaft. All other engines are equipped with a rotary type oil pump. The pump is mounted at gear end of

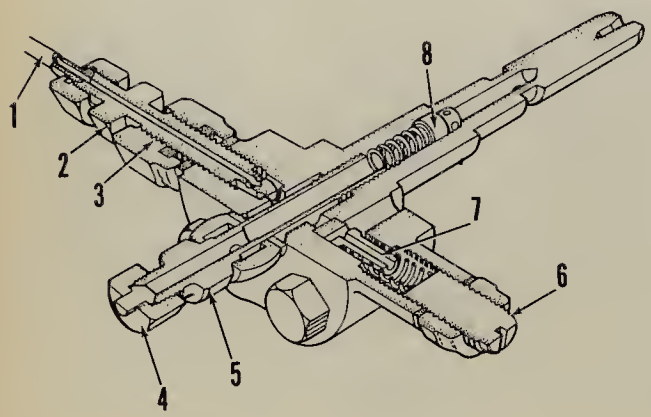


Fig. PE-56—Cross-sectional view of plunger type oil pump assembly used on early PH1 engines.
1. Oil pipe to valve rockers
2. Oil restrictor valve
3. Locknut
4. Union nut
5. Fulcrum pin
6. Pressure adjusting screw
7. Relief valve poppet
8. Check valve

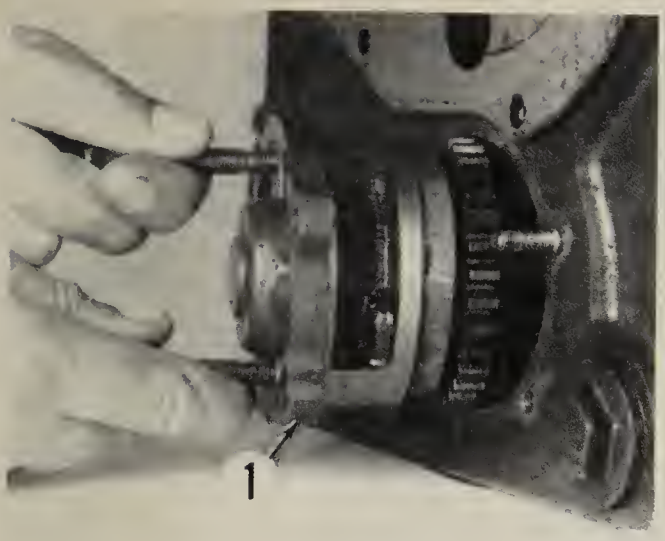


Fig. PE-58—Use two cap screws in threaded holes provided in pump flange to pull pump assembly (1) from crankcase.

Fig. PE-59—Exploded view of rotary type engine oil pump assembly.

1. Pump body
2. Dowels
3. Outer rotor
4. Inner rotor
5. Cover
6. Drive gear
7. Retaining pin

crankcase and driven by the crankshaft gear via an idler gear.

Plunger Pump

R&R AND OVERHAUL. To remove oil pump assembly, first drain the oil. Remove crankcase inspection cover. Remove the oil strainer. Disconnect oil pipes from pump and flywheel end main bearing. Remove crankshaft as outlined in CRANKSHAFT section. Withdraw pump assembly by pulling towards flywheel end of crankcase.

Disassemble pump and check components for wear. Count the number of turns required to remove relief valve adjusting screw (6–Fig. PE-56) so it can be reinstalled at approximately the same pressure setting. It is important that the pin (2–Fig. PE-57) securing the pump plunger (3) to crankshaft strap (1) be renewed as oil pump will not function if pin failure occurs.

Be sure all parts are clean and lubricated with oil before reassembling. Install relief valve adjusting screw same number of turns as required to remove screw. Reinstall pump by reversing the removal procedure.

Adjust the oil feed rate to valve rockers as follows: Loosen oil pipe union nut and locknut (3–Fig. PE-56). Turn oil restrictor valve (2) completely in, then turn valve back out 1/6 of a turn. Tighten locknut and oil pipe union nut.

Check and adjust engine oil pressure as follows: Remove union nut (4) and connect a pressure gage at this point. With engine at normal operating temperature and running at rated speed, oil pressure should be 240 kPa (35 psi). If necessary, turn adjusting screw (6) clockwise to increase pressure or counterclockwise to decrease pressure.

Rotary Oil Pump

R&R AND OVERHAUL. To remove oil pump, first drain oil from sump. Remove pump mounting cap screws, then screw two bolts into threaded holes provided in pump flange and pull pump from crankcase (Fig. PE-58). The pump drive idler gear is mounted on a shaft in the crankcase and retained by a washer and snap ring. Idler gear is accessible through crankcase inspection cover opening.

To disassemble pump, remove gear retaining pin (7–Fig. PE-59) and drive gear (6). Remove cover mounting screws and separate cover (5) from pump body. All parts should be lubricated with oil during assembly.

To reinstall pump, reverse the removal procedure.

Relief Valve

The oil pressure relief valve is located in the oil filter mounting bracket. When removing valve, count the number of turns required to remove the adjusting screw so it can be reinstalled at approximately the same pressure setting.

Engine oil pressure should be checked with engine at normal operating temperature and running at rated speed. Recommended oil pressure is 270-310 kPa (40-45 psi). If necessary, turn adjusting screw clockwise to increase pressure or counterclockwise to reduce pressure.

PEUGEOT

PEUGEOT MOTORS OF AMERICA, INC.
INDUSTRIAL ENGINE DIVISION
One Peugeot Plaza
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Model	No. Cyls.	Bore	Stroke	Displ.
XDP4.88	4	88 mm (3.465 in.)	80 mm (3.150 in.)	1946 cc (118.7 cu.in.)
XDP4.90	4	90 mm (3.543 in.)	83 mm (3.268 in.)	2112 cc (128.9 cu.in.)
XD2P4.94	4	94 mm (3.700 in.)	83 mm (3.268 in.)	2304 cc (140.6 cu.in.)
XD2PS	4	94 mm (3.700 in.)	83 mm (3.268 in.)	2304 cc (140.6 cu.in.)
XC2PT	4	94 mm (3.700 in.)	83 mm (3.268 in.)	2304 cc (140.6 cu.in.)

Peugeot engines covered in this section are four-stroke, liquid-cooled diesel engines. Models XD2PS and XD2PT are turbocharged. All engines have a cast iron cylinder block and aluminum cylinder head.

Cylinders are numbered 1 through 4 with number 1 cylinder nearest flywheel. Firing order is 1-3-4-2. Crankshaft rotation is counterclockwise at flywheel end.

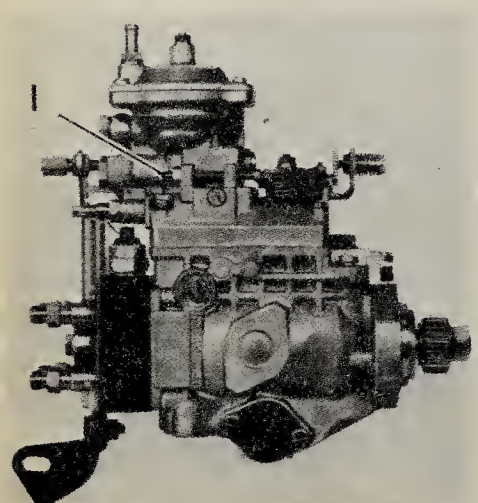


Fig. P1-1—Low idle speed on Bosch fuel injection pump is adjusted by turning screw (I).

MAINTENANCE

LUBRICATION

Recommended oil is API classification CD. Oil viscosity should be SAE 30 for ambient temperatures above 15°C (59°F), SAE 20 for ambient temperatures between minus 7°C (20°F) and plus 15°C (59°F), and SAE 10 for ambient temperatures below minus 7°C (20°F).

The engine is equipped with a pressurized oil system. Oil pressure at working speed should be 300 kPa (44 psi) with oil temperature at 80°C (176°F).

ENGINE SPEED ADJUSTMENT

Low idle speed should be 700-750 rpm on Models XDP 4.88 and XDP 4.90, 800-850 rpm on Model XD2P 4.94 and 750-800 rpm on Models XD2PS and XD2PT.

Low idle speed on models equipped with Bosch fuel injection pump is adjusted by turning screw (I-Fig. P1-1).

To adjust low idle speed on engines equipped with a Roto Diesel injection pump and variable speed control, be sure idle speed control is set for slow idle speed (not fast idle) and turn adjuster at pump end of idle control cable. To adjust idle speed on fixed speed engines with Roto Diesel injection pump, turn idle speed screw (I – Fig. P1-2). Adjust throttle stop screw so engine decelerates to idle speed without stalling. Note on fixed speed engines that an electrical device stops engine, however, in case electrical stop device malfunctions, idle lever stop (P) may be rotated so idle speed lever will completely close pump fuel circuit thereby stopping engine.

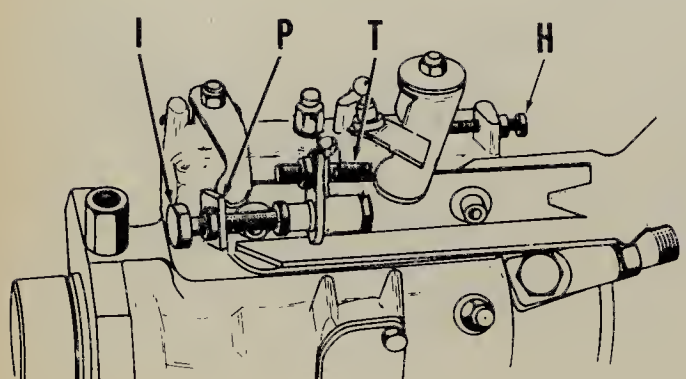


Fig. P1-2—Drawing showing location of idle speed screw (I) and high speed screw (H) on fixed speed engines with Roto Diesel injection pump. Refer to text for adjustment.

FUEL SYSTEM

FUEL FILTER. The fuel filter should be drained after every 50 hours of operation or more often to remove contaminants. Filter element should be renewed after every 200 hours of operation.

BLEED FUEL SYSTEM. To bleed fuel system on engines equipped with

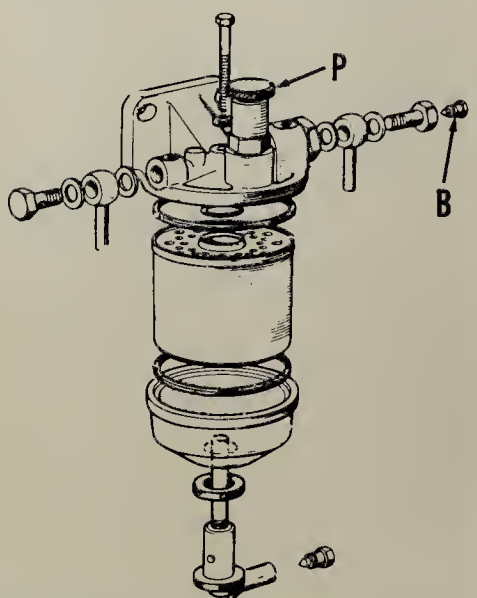


Fig. P1-3—View of fuel filter used on engines equipped wtih Roto Diesel fuel injection pump.

Fig. P1-4—View of fuel filter used on models equipped wtih Bosch fuel injection pump.

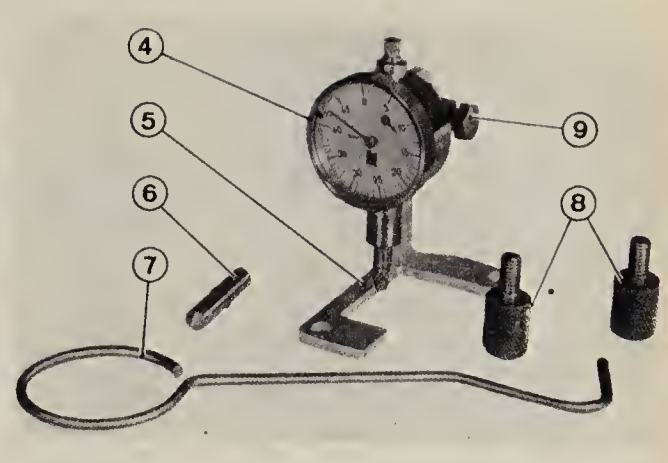


Fig. P1-6—Use the tools shown to time Roto Diesel fuel injection pump as outlined in text.

4. Dial gage
5. Gage holder
6. Timing pin
7. Anti-backlash tool
8. Holder screws
9. Gage mounting screw

Roto Diesel injection pump, open fuel tank valve and fuel filter bleed screw (B–Fig. P1-3). Operate pump handle (P) until air-free fuel flows from bleed screw hole. Close filter bleed screw. Open fuel injection pump bleed screw and operate filter pump handle until air-free fuel exits pump bleed screw hole. Close pump bleed screw. Loosen fuel injection lines at injectors. With throttle open, rotate crankshaft until air-free fuel flows from injection lines, then reconnect lines.

To bleed fuel system on engines equipped with Bosch injection pump, open fuel tank valve and open bleed screw (1–Fig. P1-4). Operate filter pump handle (P) until air-free fuel is discharged from hose (H), then close bleed screw (1). Open screw (2) and operate pump handle until resistance is felt, then close screw. Loosen injection pump inlet fitting and allow fuel to flow until air is expelled, then tighten fitting. Loosen fuel injection lines at injectors. With throttle open, rotate crankshaft until air-free fuel flows from injection lines, then reconnect lines.

INJECTION PUMP TIMING. Number 4 piston (number 4 cylinder is nearest timing gear end of engine) must be placed in firing position to check injection timing or install and time injection pump. To determine piston position, remove valve cover without dislodging push rod from cam follower, disconnect exhaust rocker arm of number 4 cylinder from push rod. Rotate rocker arm away from number 4 cylinder exhaust valve. Using a suitable spring compressor, remove exhaust valve spring. Allow exhaust valve to rest on piston, then mount a dial gage so gage contacts valve stem thereby reading piston travel. Be sure valve does not bind in valve guide. Rotate crankshaft so number 4 piston is on compression and at firing position listed in the following table:

Model	Degrees BTDC	Piston Position BTDC
XDP 4.88*	24°	4.29-4.39 mm (0.169-0.173 in.)
XDP 4.90	25°	4.86-4.96 mm (0.191-0.195 in.)
XD2P 4.94	24°	4.49-4.59 mm (0.177-0.180 in.)
XD2PS, XD2PT	...	0.78-0.82 mm (0.031-0.032 in.)

*Timing specifications in table are for Model XDP 4.88 engines which operate at speeds in excess of 3000 rpm. For Model XDP 4.88 engines operated at 3000 rpm or less, degrees BTDC are 15°and piston position BTDC is 1.67-1.77 mm (0.066-0.069 inch).

After number 4 piston has been placed in timing position, refer to appropriate following section. Stamp timing marks on engine for future reference.

ROTO DIESEL PUMP. With number 4 piston in firing position as previously outlined, remove pump inspection plate (1–Fig. P1-5) and note timing groove (2) in pump drive sleeve. If pump is separated from engine, rotate drive gear so groove (2) is aligned with timing pin guide (3). If pump is mounted on engine, groove (2) should be near timing pin guide (3), if not, remove pump and rotate drive gear. Install timing pin (6–Fig. P1-6) and dial gage as shown in Fig. P1-7. If not installed, mount pump on engine and tighten support plate screws to 20-24 N·m (15-18 lbs.-ft.). Pump retaining nuts must be just loose enough to rotate pump. Install anti-backlash tool (7–Fig. P1-6) as shown in Fig. P1-7, then rotate pump until maximum dial gage reading is obtained and tighten pump retaining nuts to 15-20 N·m (11-15 ft.-lbs.). Timing marks should be stamped on pump support plate and pump flange for future reference. Remove timing tools and install inspection plate.

BOSCH PUMP. With number 4 piston in firing position as previously outlined,

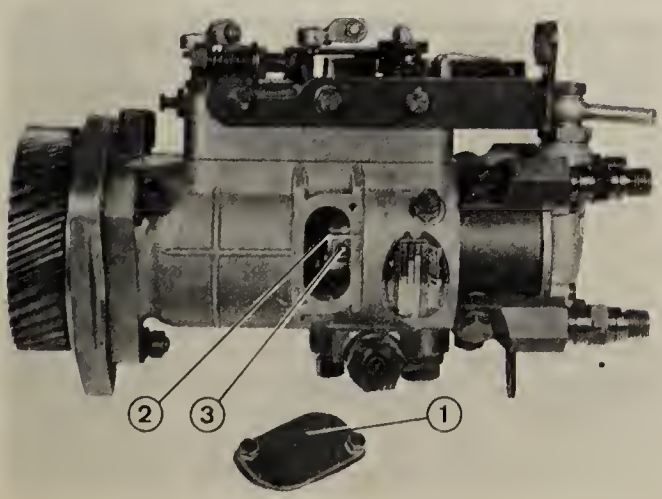


Fig. P1-5—View of Roto Diesel fuel injection pump with inspection plate (1) removed showing timing groove (2) and timing pin guide (3).

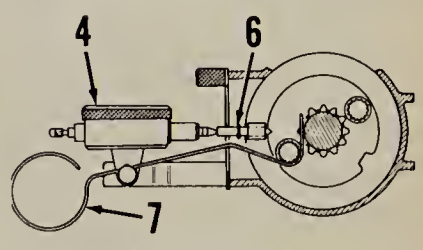


Fig. P1-7—Install timing tools as shown to time Roto Diesel fuel injection pump.

unscrew plug (2 – Fig. P1-8) and install a dial gage to measure pump plunger travel. If pump is separated from engine, install pump noting drive gear master spline (1). Tighten pump retaining screws so pump is secure but can still be rotated. If not previously marked, stamp marks on block and flywheel or pulley to indicate number 4 piston timing position. Rotate crankshaft and zero dial gage at bottom dead center of pump plunger travel. Rotate crankshaft and return to number 4 piston timing position. Rotate pump so dial gage indicates 0.29-0.31 mm (0.0114-0.0122 inch) and tighten pump screws to 15-20 N·m (11-15 ft.-lbs.). Timing marks should be stamped on pump support plate and mounting flange for future reference. Remove timing tools.

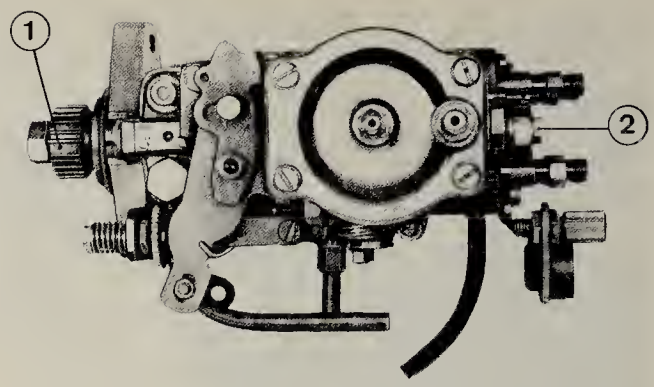


Fig. P1-8—View of Bosch fuel injection pump. Note drive gear master spline (1).

COOLING SYSTEM

All engines are liquid-cooled and equipped with a water pump to circulate coolant. Due to aluminum construction of cylinder head, an ethylene glycol based antifreeze solution or anticorrosive additive should be used in coolant.

Thermostat opening temperature is 65°C (150°F).

REPAIRS

TIGHTENING TORQUES

Refer to the following table for special tightening torques. All fasteners are metric.

Camshaft retainer	15-20 N·m (11-15 ft.-lbs.)
Connecting rod	52-61 N·m (38-45 ft.-lbs.)
Cylinder head	
With flanged injectors	64-68 N·m (47-50 ft.-lbs.)
With threaded injectors:	
XDP4.88, XDP4.90	59 N·m (44 ft.-lbs.)
XD2P4.94, XD2PS, XD2PT	78 N·m (58 ft.-lbs.)
Exhaust manifold	20-24 N·m (15-18 ft.-lbs.)
Flywheel	
XDP4.88	64-68 N·m (47-50 ft.-lbs.)
All other engines	74-78 N·m (55-58 ft.-lbs.)
Injection pump	15-20 N·m (11-15 ft.-lbs.)
Injection pump gear	
Bosch	5-7 N·m (45-60 in.-lbs.)
Roto Diesel	22-25 N·m (16-19 ft.-lbs.)
Injection pump support plate	20-24 N·m (15-18 ft.-lbs.)
Injector	
Flange type	15-20 N·m (11-15 ft.-lbs.)
Threaded type	88 N·m (65 ft.-lbs.)
Intake manifold	20-24 N·m (15-18 ft.-lbs.)
Main bearing	98-117 N·m (72-86 ft.-lbs.)
Oil pan	8-12 N·m (6-9 ft.-lbs.)
Oil pump cover	5-7 N·m (45-60 in.-lbs.)
Timing gear cover	8-12 N·m (6-9 ft.-lbs.)
Water pump	8-12 N·m (6-9 ft.-lbs.)
Water pump pulley nut	30-39 N·m (22-29 ft.-lbs.)

VALVE ADJUSTMENT

Valve clearance is adjusted with engine cold. During normal engine operation, valve clearance should be checked and adjusted after every 400 hours of operation. Refer to the following table for recommended clearances.

Model	Intake	Exhaust
XDP4.88, XDP4.90	*0.15-0.20 mm (0.006-0.008 in.)	*0.25-0.30 mm (0.010-0.012 in.)
XD2P4.94	0.30-0.35 mm (0.012-0.014 in.)	0.30-0.35 mm (0.012-0.014 in.)
XD2PS, XD2PT	0.15 mm (0.006 in.)	0.25 mm (0.010 in.)

*After removing and reinstalling cylinder head on engines equipped with flanged injectors, valve clearance should be initially adjusted to 0.25-0.30 mm (0.010-0.012 inch) for intake and 0.35-0.40 mm (0.014-0.016 inch) for exhaust. After 20 to 50 hours of operation, readjust to specifications given in table.

ROCKER ARMS AND SHAFT

R&R AND OVERHAUL. Remove valve cover for access to rocker arm shaft assembly. Unscrew retaining nuts and lift off rocker shaft. Push rods may be removed by carefully separating push rod from cam follower so cam follower does not leave its bore.

Rocker arms and shaft are lubricated by engine oil routed through an external oil line to cylinder head, then through an oil passageway to oil sleeve (4 – Fig. P1-9).

Minimum rocker shaft diameter is 18.96 mm (0.746 inch). Rocker arm bushing is renewable.

When assembling rocker shaft assembly, install oil sleeve (4) on shaft so chamfered hole in shaft is aligned with screw hole in sleeve. Place copper washer (6) on oil sleeve locating screw (5) then install and tighten screw to 5-7

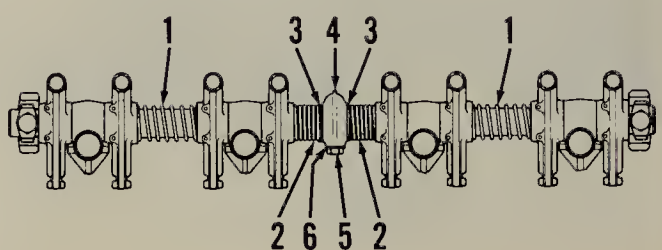


Fig. P1-9—View of rocker shaft assembly on Model XD2P4.94. Other models are similar.

1. Strong spring
2. Weak spring
3. Washer
4. Oil sleeve
5. Locating screw
6. Copper washer

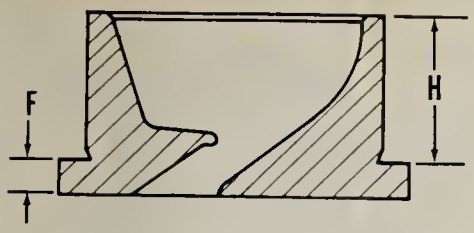


Fig. P1-10—Turbulence chamber flange thickness (F) is 3.975-4.025 mm (0.1565-0.1585 inch) while height (H) is 18.50-18.80 mm (0.728-0.740 inch).

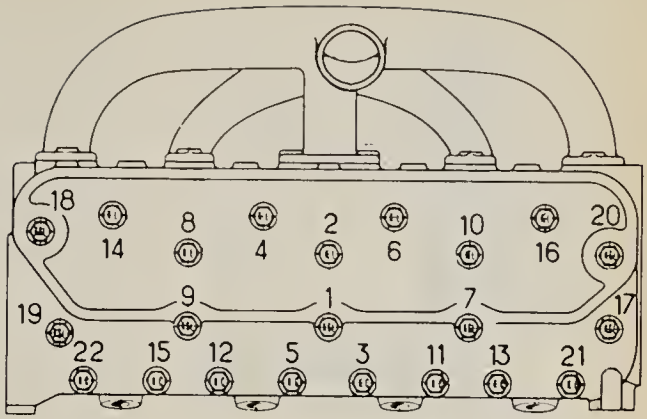


Fig. P1-11—Cylinder head bolt tightening sequence for XDP4.88 and XDP4.90 engines equipped with flanged injectors.

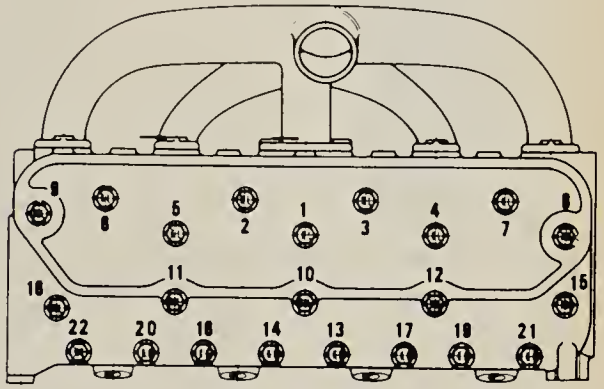


Fig. P1-12—Cylinder head bolt tightening sequence for all engines except XDP4.88 and XDP4.90 engines equipped with flanged injectors.

N·m (45-60 in.-lbs.). Note that washers (3) and weak springs (2) are adjacent to oil sleeve. On models with rocker shaft stands at end of shaft, insert a 0.1 mm (0.004 inch) thick shim between numbers 1 and 4 intake rocker arms and outer shaft stands. Insert push rods, then install rocker shaft assembly being sure rubber gasket is installed on oil sleeve nipple. Tighten rocker shaft retaining nuts to 49 N·m (36 ft.-lbs.), and on models so equipped, tighten outer rocker shaft stand screws to 20 N·m (15 ft.-lbs.). Remove shims from rocker shaft ends and be sure rocker arms rotate freely.

CYLINDER HEAD

R&R AND OVERHAUL. Drain coolant, then detach coolant hoses and water pump belt. If desired, remove water pump. Disconnect fuel injection lines, remove injectors and cap or plug fuel openings to prevent contamination. Disconnect glow plug wire. Remove intake and exhaust manifolds. Detach external oil line from head. Remove rocker shaft and push rods as previously outlined. Unscrew cylinder head screws and remove head.

Cylinder head surface should be machined if warped more than 0.2 mm (0.008 inch) or uneveness exceeds 0.1 mm (0.004 inch). Minimum cylinder head height is 89.35 mm (3.518 inches).

NOTE: Turbulence chambers must be removed from head prior to machining head surface.

Turbulence chamber standout above head surface should be 0.0-0.03 mm (0.0-0.001 inch). To remove turbulence chamber, insert a malleable punch through injector hole and drive out chamber. Flange thickness (F-Fig. P1-10) should be 3.975-4.025 mm (0.1565-0.1585 inch) while height of chamber (H) should be 18.50-18.80 mm (0.728-0.740 inch). Clearance between bottom of bore in head and chamber should be 0.1-0.6 mm (0.004-0.023 inch). Oversize turbulence chambers are available. Be sure retaining ball is installed in groove when installing turbulence chamber.

Valve seats and guides are renewable with oversizes available. Install valve guide so tip of guide is 27.95-28.05 mm (1.100-1.104 inches) from head mating surface. Ream guide to inner diameter of 8.520-8.542 mm (0.335-0.336 inch). Intake valve seat angle is 45° on Models XDP4.88 and XDP4.90 and 30° on all other models. Exhaust valve seat angle is 45° for all models.

Three thicknesses of cylinder head gasket are used. Head gasket with thickness of 1.40 mm (0.055 inch) is used on Models XDP4.88 and XDP4.90. To select gasket thickness on all other models, measure piston height above block surface with piston at TDC. If piston standout is lower than 0.84 mm (0.033 inch) on Model XD2P4.94 or lower than 0.79 mm (0.031 inch) on Models XD2PS or XD2PT, install 1.58 mm (0.062 inch) thick head gasket. If piston standout is higher than 0.84 mm (0.033 inch) on Model XD2P4.94 or higher than 0.79 mm (0.031 inch) on Models XD2PS or XD2PT, install 1.70 mm (0.067 inch) thick head gasket.

Cylinder head and gasket surfaces must be clean and dry. Do not apply any sealing compound to gasket. Refer to appropriate head bolt tightening sequence shown in Fig. P1-11 or P1-12 and tighten bolts as follows: On engines equipped with flanged injectors, tighten head bolts in two steps with a final torque of 64-68 N·m (47-50 ft.-lbs.). Then, loosen each bolt ¼ turn one at a time and retighten to specified torque. Adjust valve clearance as outlined in VALVE ADJUSTMENT paragraph. After the first 1 to 2 hours of operation and again between 20 to 50 hours of operation, cylinder head bolts should be loosened ¼ turn and retorqued (using appropriate tightening sequence). On engines equipped with threaded injectors, tighten head bolts in two steps (following sequence shown in Fig. P1-12) to torque specified in TIGHTENING TORQUES paragraph. Then, loosen and retorque bolts one at a time in proper sequence. Start engine and operate at 3000 rpm for 10 minutes. Stop engine and allow to cool for four hours, then loosen bolts one at a time and retighten to specified torque two times following proper sequence each time.

VALVE SYSTEM

Both valves ride in renewable valve guides and seat in renewable seat inserts. Refer to CYLINDER HEAD section for guide and seat installation.

Intake valve face and seat angles are 45° on Models XDP 4.88 and XDP 4.90 and 30° for all other models. Exhaust valve face and seat angles are 45° for all models. Intake and exhaust valve guide inside diameter is 8.520-8.542 mm (0.335-0.336 inch). Intake valve stem diameter is 8.473-8.495 mm (0.3336-

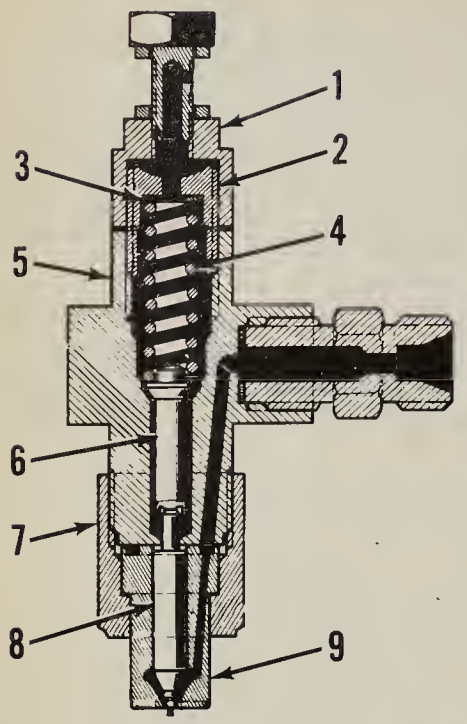


Fig. P1-13—Cross-sectional view of Roto Diesel injector.

1. Cap nut
2. Adjusting nut
3. Washer
4. Spring
5. Injector body
6. Push rod
7. Nozzle nut
8. Nozzle valve
9. Nozzle

0.3344 inch) and exhaust valve stem diameter is 8.453-8.475 mm (0.3328-0.3336 inch). Distance from top of valve to head surface should be 0.75-1.15 mm (0.030-0.045 inch).

Inner valve spring free length is 41 mm (1.614 inches) and outer valve spring free length is 44.6 mm (1.756 inches). Inner valve spring pressure is 181 newtons (41 pounds) at 21.5-22.5 mm (0.846-0.885 inch). Outer valve spring pressure is 451 newtons (101 pounds) at 25.5-26.5 mm (1.004-1.043 inches).

INJECTOR

WARNING: Fuel emerges from injector with sufficient force to penetrate the skin. When testing injector, keep yourself clear of nozzle spray.

Model XDP 4.88, XDP 4.90 and XD2P 4.94 are equipped with flange type Roto-Diesel injectors. Models XD2PS and XD2PT are equipped with screw type Bosch injectors. Refer to appropriate following section for service.

ROTO DIESEL INJECTORS. Prior to removing injector, thoroughly clean injector, lines and surrounding area using compressed air and a suitable solvent.

TESTING. A complete job of testing and adjusting injectors requires use of special test equipment. Only clean, approved testing oil should be used to test injectors. Injector nozzle should be tested for opening pressure, seat leakage and spray pattern.

When operating properly during test, injector nozzle will emit a buzzing sound and cut off quickly with no fluid leakage at seat.

Before conducting test, operate tester lever until test oil flows, then attach injector. Close valve to tester gage and pump tester lever a few quick strokes to be sure nozzle valve is not stuck, which would indicate that injector may be serviceable without disassembly.

Opening pressure is adjusted by turning adjusting nut (2–Fig. P1-13). Refer to following table for opening pressure on Roto Diesel injection nozzles:

Injector Type	Opening Pressure
RDN OSDC 6577	11000-12000 kPa (1595-1740 psi)
RDN 12 SD 6236	13500-14500 kPa (1960-2100 psi)
RDN 12 SD 6517	12300-13300 kPa (1785-1930 psi)
RDN 45 D 6432	11500-12500 kPa (1670-1815 psi)

The nozzle tip should not leak when injector fluid is pressurized to 2000 kPa (300 psi) below opening pressure. Hold pressure for 10 seconds; if drops appear or nozzle tip becomes wet, valve is not seating and injector must be overhauled.

The injector spray pattern should be well atomized, conical and emerge from nozzle tip in a straight axis. If pattern is wet, ragged or intermittent, nozzle must be overhauled or renewed.

NOTE: Be sure injector tester is operating properly and connections are tight, especially if similar malfunctions are found in a series of injectors.

OVERHAUL. Hard or sharp tools, emery cloth, grinding compound or other than approved solvents or lapping compounds must never be used. An approved nozzle cleaning kit is available through a number of specialized sources.

Wipe all dirt and loose carbon from exterior of nozzle and holder. Refer to Fig. P1-13 for a cross-sectional view of injector.

Secure injector body (5) in a soft jawed vise or holding fixture and disassemble injector, being careful not to drop or damage nozzle valve (8). Place all parts in a clean calibrating oil or diesel fuel as they are removed using a compartmented pan and using extra care to keep parts from each injector together and separate from other units.

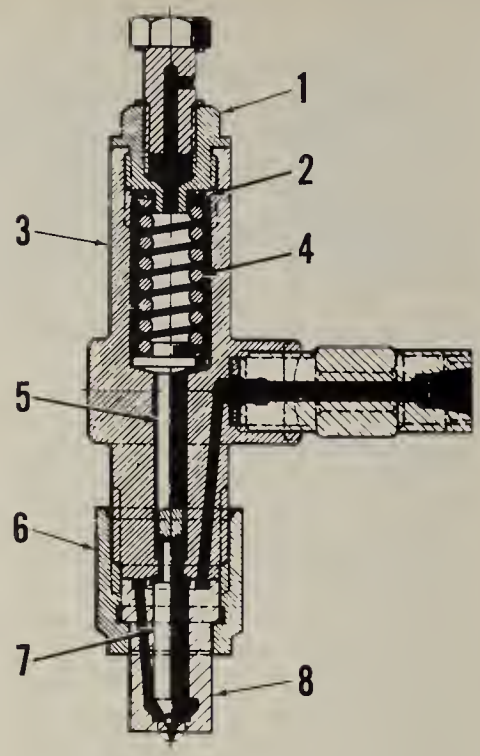


Fig. P1-14—Cross-sectional view of Bosch injector.

1. Cap nut
2. Shim
3. Body
4. Spring
5. Push rod
6. Nozzle nut
7. Nozzle valve
8. Nozzle

Clean exterior surfaces with a brass wire brush, soaking in an approved carbon solvent if necessary, to loosen hard carbon deposits. Rinse parts in clean diesel fuel or calibrating oil immediately after cleaning to neutralize the solvent and prevent etching of polished surfaces. Tighten nozzle nut (7) to 64 N·m (47 ft.-lbs.).

BOSCH INJECTORS. Prior to removing injector, thoroughly clean injector, lines and surrounding area using compressed air and a suitable solvent.

TESTING. The testing procedure for Bosch injectors is same as Roto Diesel injectors; refer to Roto Diesel section while noting the following.

Opening pressure for Bosch injectors should be 11000-12000 kPa (1595-1740 psi) for XDP4.90 and XD2P4.94 engines or 12500-13500 kPa (1815-1960 psi) on XD2PS and XD2PT engines. Opening pressure is adjusted by varying thickness of shim (2–Fig. P1-14). A change in shim thickness of 0.10 mm (0.004 inch) will change opening pressure approximately 500 kPa (75 psi).

GLOW PLUGS

Each cylinder is equipped with a glow plug. Glow plugs are connected in parallel with each glow plug grounded through mounting threads. Before

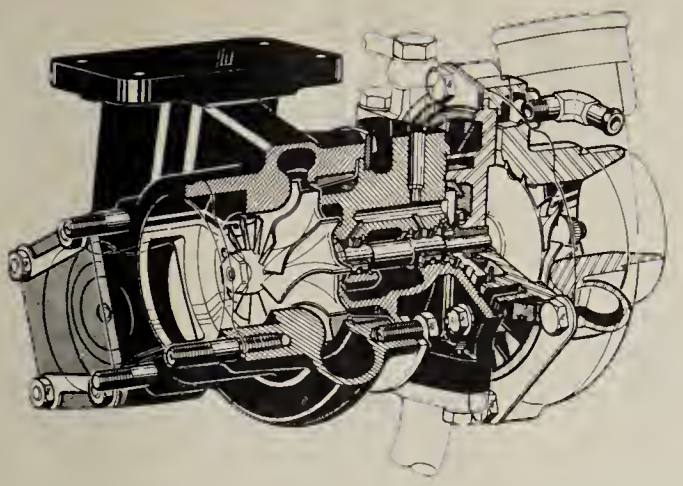


Fig. P1-15—Cutaway drawing of Garret AiResearch Model T03 turbocharger used on Models XD2PS and XD2PT.

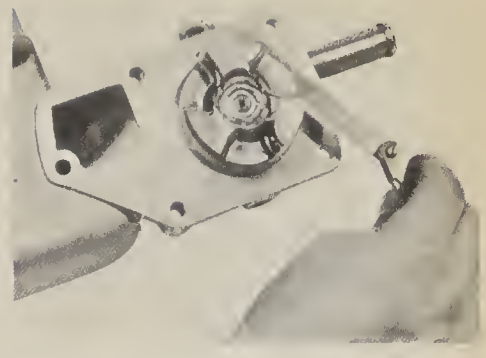


Fig. P1-17—Measure clearance between water pump flange and impeller. Maximum clearance is 1mm (0.040 inch).

suspecting a glow plug malfunction, determine that current is reaching glow plugs. To check individual glow plugs, remove electrical strap between glow plugs. With negative battery terminal grounded to engine, connect a test light between positive battery terminal and glow plug electrode. If test light turns on, then glow plug is good. If test light remains off, then glow plug is defective and must be renewed.

INJECTION PUMP

To remove injection pump, disconnect fuel lines and cap openings to prevent contamination. Disconnect control cables and remove rear pump support. On Models XD2PS and XD2PT, unscrew two Allen screws retaining injection pump and separate pump from engine. On all other models, remove screws securing pump support plate and separate pump with plate from engine.

The injection pump should be tested and overhauled by a shop qualified in diesel injection pump repair.

If removed, install gear on gear driven models or splined hub on chain driven models. Refer to INJECTION PUMP TIMING section and install pump. Refer to ENGINE SPEED ADJUSTMENT section if idle or high engine speed requires adjustment.

TURBOCHARGER

Models XD2PS and XD2PT

A Garret AiResearch Model T03 turbocharger is used on Models XD2PS and XD2PT. Refer to Fig. P1-15 for a cutaway drawing of turbocharger. Oil to lubricate and cool turbocharger bearings is provided by pressurized engine oil routed through an external oil line. Return oil is directed to a fitting in side of engine block.

The turbocharger is equipped with an integral wastegate which regulates turbocharger at a maximum pressure of 60 kPa (8.7 psi). The wastegate valve (V-Fig. P1-16) is seated in turbine housing by spring (S) with the valve stem attached to diaphragm (D). When pressure in compressor housing (C) reaches 60 kPa (8.7 psi), diaphragm (D) overcomes spring pressure and moves the valve off its seat. Exhaust gases bypass the turbocharger turbine thereby reducing turbine and compressor speed which results in reduced pressure in compressor housing. Spring force seats the wastegate valve (V) and the cycle repeats.

REMOVE AND REINSTALL. Removal of unit is apparent with inspection. Turbocharger must be serviced as a unit assembly as overhaul is accomplished at factory. When installing turbocharger, oil cavity of center housing should be filled with oil and oil line from engine should be primed with oil. This procedure is necessary to prevent dry starting of turbocharger and possible early failure of bearings.

WATER PUMP

R&R AND OVERHAUL. To remove water pump, drain coolant, disconnect hoses and remove drive belt. Unbolt and remove water pump. Using a suitable puller, pull impeller off shaft. Disassemble remainder of pump.

When assembling water pump, press impeller on shaft so there is a maximum clearance of 1 mm (0.040 inch) between impeller and pump flange (Fig. P1-17).

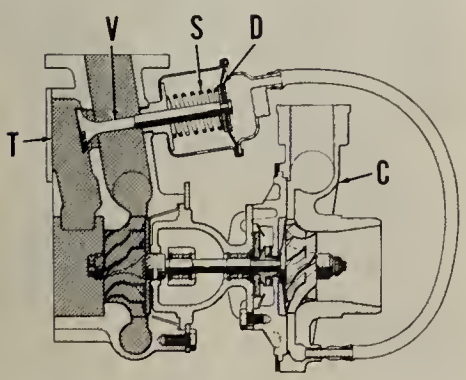


Fig. P1-16—Cross-sectional view of turbocharger and wastegate used on Models XD2PS and XD2PT.

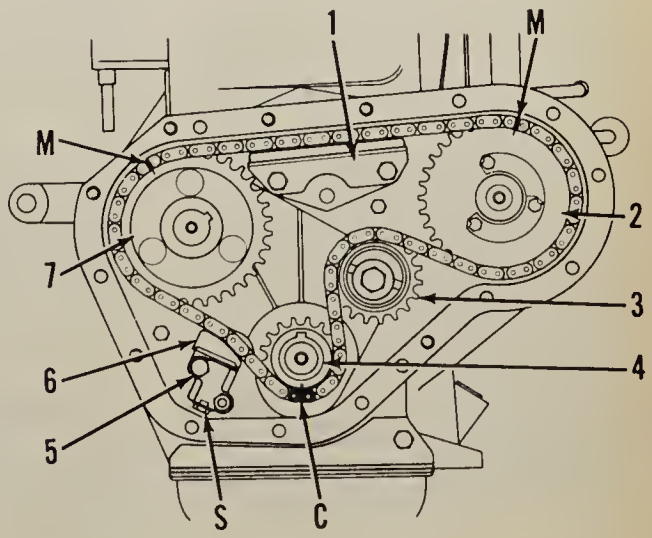


Fig. P1-18—Drawing showing timing chain and sprockets on models so equipped.

1. Rubbing block
2. Injection pump sprocket
3. Idler sprocket
4. Crankshaft sprocket
5. Tensioner
6. Tensioner shoe
7. Camshaft sprocket

C. Copper plated link
M. Timing marks
S. Adjusting screw

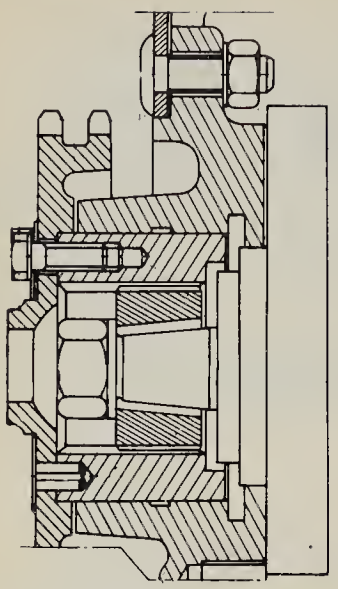


Fig. P1-19—Cross-sectional view of injection pump sprocket carrier on models equipped with a timing chain.

TIMING CHAIN AND SPROCKETS

All Models So Equipped

CHAIN TENSION ADJUSTMENT. Chain slack is removed during engine operation by a hydraulically actuated chain tensioner (5–Fig. P1-18) which uses pressurized engine oil to force chain tensioner shoe (6) against the timing chain.

To adjust chain tensioner, loosen idler (3) retaining nut. Turn idler eccentric counterclockwise so gap between chain tensioner body (5) and shoe (6) is 0.5-1.0 mm (0.020-0.040 inch). Tighten idler retaining nut to 49 N·m (36 ft.-lbs.). Turn tensioner adjusting screw (S) so shoe (6) bounces against chain. Loosen rubbing block (1) nuts and place a straightedge on chain from camshaft to injection pump sprockets to back up chain. Press rubbing block (1) against chain and tighten nuts.

REMOVE AND REINSTALL. Timing chain and sprockets are accessible after removing chain cover. The injection pump must be removed if chain and sprockets are to be removed. Loosen idler sprocket retaining nut and rotate idler eccentric to loosen chain. Unscrew injection pump sprocket (2–Fig. P1-18), then remove sprocket while disengaging chain. If required, remove camshaft, crankshaft and idler sprockets.

Refer to Fig. P1-19 for a cross-sectional view of injection pump sprocket carrier. If sprocket or carrier assembly is renewed, check clearance between sprocket hub and timing chain cover with gasket installed. Clearance should be 0.06-0.94 mm (0.002-0.037 inch).

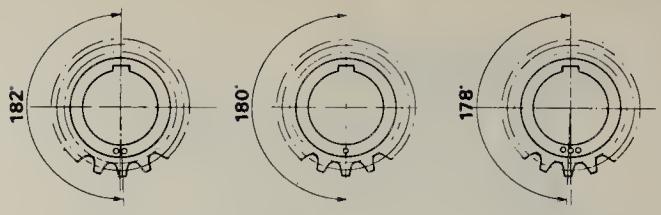


Fig. P1-20—View of crankshaft sprocket timing marks on factory installed sprockets.

The camshaft sprocket must be heated to 250°C (482°F) prior to installation on camshaft end. There must be 0.05-0.15 mm (0.002-0.006 inch) clearance between camshaft sprocket hub and camshaft retainer.

Note in Fig. P1-20 the three timing mark configurations used on the crankshaft sprocket of new engines. Replacement crankshaft sprockets have only one timing mark.

To install timing chain, wrap chain around injection pump sprocket so marks (M–Fig. P1-18) on chain and sprocket are aligned. Engage chain with camshaft, crankshaft and idler sprockets so copper plated link (C) is opposite crankshaft sprocket timing mark and marks (M) on chain and camshaft sprocket are aligned. Tighten injection pump sprocket screws to 5-7 N·m (45-60 in.-lbs.) on Bosch pump or 22-25 N·m (16-19 ft.-lbs.) on Roto Diesel pump. Refer to CHAIN TENSION ADJUSTMENT section and adjust timing chain tension as outlined. Install injection pump and timing chain cover. Tighten timing cover screws and nuts to 8-12 N·m (6-9 ft.-lbs.).

TIMING GEARS

All Models So Equipped

Crankshaft, camshaft and idler gears are accessible after removing timing gear cover. Remove injection pump to service injection pump drive gear.

To install camshaft gear, heat gear to 250°C (482°F) prior to installation on camshaft end. There must be 0.05-0.15 mm (0.002-0.006 inch) clearance between camshaft retainer and gear hub.

End play of idler gear on idler shaft should be 0.05-0.35 mm (0.002-0.014 inch).

Timing gears are stamped with timing marks which must be aligned during assembly. Tighten timing cover screws and nuts to 8-12 N·m (6-9 ft.-lbs.). Install injection pump as previously outlined.

OIL PUMP

R&R AND OVERHAUL. To remove oil pump, remove oil pan, then unscrew flange screw (F–Fig. P1-21) and taper screw (R). Oil pump is serviced as a unit assembly.

To install pump, insert pump into cylinder block so taper hole in body is aligned with taper screw (R) and install screw with copper washer. Tighten screw to 20-24 N·m (15-18 ft.-lbs.). Install flange screw (F) without a gasket and lightly tighten. Measure gap between flange screw (F) and boss as shown in Fig. P1–21. Select and install a shim 0.05-0.10 mm (0.002-0.004 inch) thicker than measured gap. Tighten flange screw to 79-98 N·m (58-72 ft.-lbs.).

PISTON AND ROD UNITS

REMOVE AND REINSTALL. Piston and connecting rod may be removed after removing cylinder head and oil pump. Unscrew rod cap retaining nuts, remove rod cap and extract piston and rod.

Connecting rod marks and indentation in piston crown must be on same side. Install piston and rod so piston crown indentation is towards injection pump side of engine. Tighten rod nuts to 52-61 N·m (38-45 ft.-lbs.).

PISTON AND RINGS

Model XDP4.88 and XDP4.90 pistons are equipped with three compression rings and an oil control ring (Fig. P1-22). Model XD2P4.94, XD2PS and XD2PT pistons are equipped with two compression rings and an oil control ring (Fig. P1-23).

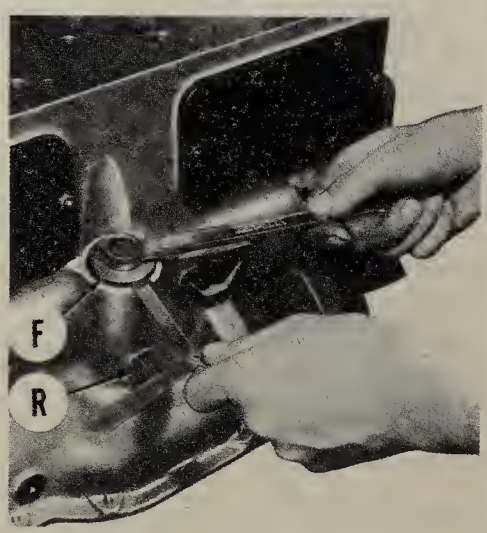


Fig. P1-21—Measure clearance between flange screw (F) and boss as outlined in text. Taper screw (R) holds oil pump in block.

Pistons of Models XCP4.88 and XDP 4.90 are classed "A" or "B" according to piston size. Piston size should be matched with cylinder liner. Refer to CYLINDER LINER section. Piston class letter is stamped on piston crown. Class A piston diameter is 87.700-87.730 mm (3.4528-3.4539 inches) for Model XDP4.88 and 89.705-89.735 mm (3.5317-3.5329 inches) for Model XDP4.90. Class B piston diameter is 87.720-87.750 mm (3.4535-3.4547 inches for Model XDP4.88 and 89.725-89.755 mm (3.5325-3.5336 inches for Model XDP4.90. Piston diameter is measured perpendicular to piston pin, 74 mm (2-15/16 inches) froom bottom of piston shirt. Piston clearance should be 0.27-0.32 mm (0.0126 inch) for Model XDP4.88 or 0.295-0.315 mm (0.0116-0.0124 inch) for Model XDP4.90 using piston diameter previously listed.

Pistons of Models XD2P4.94, XD2PS and XD2PT are classed "A" through "H" according to piston size. Piston class letter is stamped on piston crown. Class A pistons are standard size while class C, E and G pistons are major oversize pistons. Class B, D, F and H pistons are slightly larger than standard or oversize pistons. For instance, a class C piston is 0.200 mm (0.0079 inch) oversize and a class D piston is 0.215 mm (0.0084 inch) larger than standard. Where possible, the slightly larger piston may be installed without boring to the next oversize. Measure piston diameter perpendicular to piston pin., 76.5 mm (3 inches) from bottom of piston skirt on Model XD2P4.94 or 73.4 mm (2⅞ inches) from bottom of piston skirt on Models XD2PS and XD2PT. Piston clearance should be 0.34-0.39 mm (0.0134-0.0154 inch) on Model XD2P4.94 or 0.37-0.42 mm (0.0145-0.0165 inch) on Models XD2PS and XD2PT.

Top piston ring end gap should be 0.30-0.45 mm (0.012-0.018 inch) on Model XDP4.88, 0.38-0.63 mm (0.015-0.025 inch) on Model XDP 4.90, 0.40-0.65 mm (0.016-0.026 inch) on Model XD2P4.94 and 0.25-0.45 mm (0.010-0.018 inch) on Models XD2PS and XD2PT. Piston ring end gap for middle compression rings should be 0.30-0.45 mm (0.012-0.018 inch) on Model XDP 4.88, 0.38-0.63 mm (0.015-0.025 inch) on Model XDP4.90, 0.35-0.60 mm (0.014-0.024 inch) on Model XD2P4.94 and 0.25-0.45 mm (0.010-0.018 inch) on Models XD2PS and XD2PT. Oil control ring end gap should be 0.15-0.30 mm (0.006-0.012 inch) on Models XD2P4.94, XD2PS and XD2PT. Oil control ring on Models XDP4.88 and XDP4.90 must not be altered.

When installing rings, top compression ring (1 – Fig. P1-22 or P1-23) is a barrel face ring and may be installed either side up. Intermediate compression rings (2) have one side marked "TOP" and must be installed accordingly. U – FLEX type oil control ring (3 – Fig. P1-22) may be installed either side up, but GOETZE expander type oil ring (3 – Fig. P1-23) must be installed with side marked "TOP" facing upward.

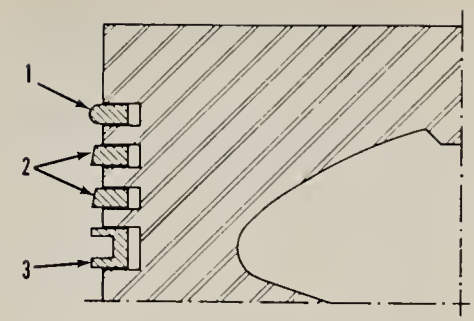


Fig. P1-22—Cross-sectional view showing proper installation of piston rings on XDP4.88 and XDP4.90 engines. Center compression rings (2) have one side marked "TOP" and must be installed accordingly.

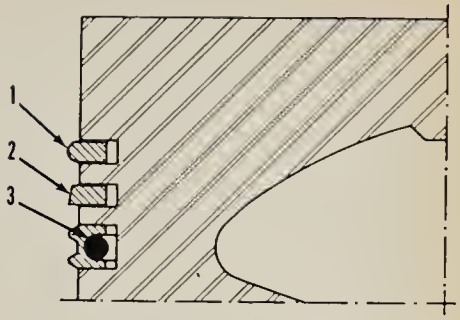


Fig. P1-23—Cross-sectional view of piston rings used on all engines except XDP4.88 and XDP4.90. Note "TOP" marking on middle compression ring (2) and oil control ring (3) when installing rings.

CYLINDER LINER

Models XDP4.88 and XDP4.90

Models XDP4.88 and XDP4.90 are equipped with wet type cylinder liners. Cylinder liner lower end is sealed by a rubber ring. Cylinder liner standout above block surface should be 0.025-0.085 mm (0.001-0.003 inch).

Cylinder liners are classed acccording to bore size to match with pistons. Refer to PISTON AND RINGS section. The liner is marked on the outer edge at bottom of bore with one or two notches. Class "A" cylinder liners have one notch and class "B" cylinder liners have two notches. Cylinder liner bore diameter of class A liners is 88.00-88.02 mm (3.4646-3.4653 inches) for Model XDP 4.88 or 90.00-90.02 mm (3.5433-3.5441 inches) for Model XDP4.90. Cylinder liner bore diameter of class B liners is 88.02-88.04 mm (3.4654-3.4661 inches) for Model XDP 4.88 or 90.02-90.04 mm (3.5441-3.5449 inches) for Model XDP 4.90.

PISTON PIN

A full floating piston pin is used in all models. Piston pin diameter is 30.000-30.006 mm (1.1811-1.1813 inches) for Models XD2PS and XD2PT or 28.000-28.006 mm (1.1024-1.1026 inches) for all other models.

CONNECTING ROD AND BEARINGS

Connecting rods are equipped with a renewable bushing in the small end and insert type bearings in the big end. Bushing inner diameter is 30.007-30.020 mm (1.1814-1.1819 inches) on Models XD2PS and XD2PT or 28.007-28.020 mm (1.1026-1.1031 inches) on all other models. Clearance between big end bearing and crankpin should be 0.040-0.092 mm (0.0016-0.0036 inch) on all models. Rod side play should be 0.010-0.025 mm (0.004-0.010 inch).

Connecting rods are graded according to weight and stamped with a number (1 through 5) or letter (A through H). Renew rod with one of same weight grade.

CAMSHAFT AND TAPPETS

R&R AND OVERHAUL. To remove camshaft, remove valve cover and push rods. Remove tappet cover and extract tappets. Remove oil pan and oil pump. Detach timing chain or gear cover, and on models so equipped, remove timing chain. Unscrew camshaft retainer plate screws and withdraw camshaft.

Camshaft journal diameter is 41.925-41.950 mm (1.6506-1.6516 inches). Camshaft bearing clearance should be 0.05-0.11 mm (0.002-0.004 inch). Standard cam follower diameter is 23.95-23.96 mm (0.9429-0.9433 inch). Oversize cam follower with a diameter of 24.15-24.16 mm (0.9508-0.9512 inch) is available. Cam follower should be 0.04-0.08 mm (0.0016-0.0031 inch).

To install camshaft, reverse removal procedure. Be sure camshaft journals and lobes are adequately lubricated. Refer to TIMING GEARS AND SPROCKETS or TIMING GEARS section to install camshaft sprocket or gear. Be sure camshaft journals and lobes are adequately lubricated. Align gear timing marks on models so equipped. Tighten camshaft retainer plate screws to 15-20 N·m (11-15 ft.-lbs.). On models equipped with a timing chain, refer to TIMING CHAIN AND SPROCKETS section and install chain. Refer to OIL PUMP section for pump installation.

CRANKSHAFT AND BEARINGS

R&R AND OVERHAUL. To remove crankshaft, remove flywheel and timing gear or chain cover. Remove timing chain on models so equipped. Remove pistons and rods. The crankshaft can be removed after detaching main bearing caps.

Standard main journal diameter is 54.994-55.021 mm (2.1651-2.1661 inches). Main bearing clearance should be 0.040-0.098 mm (0.0016-0.0038 inch) for all journals. Undersize main bearings are available.

Crankshaft end play is controlled by thrust washers attached to center main bearing. Crankshaft end play should be 0.08-0.29 mm (0.003-0.011 inch). Thrust washers are available in thicknesses of 2.30-2.33 mm (0.090-0.092 inch) and 2.50-2.53 mm (0.098-0.099 inch). Install thrust washers with smooth side towards main bearings.

Crankpin standard journal diameter is 54.994-55.021 mm (2.1651-2.1661 inches) on Models XD2PS and XD2PT, and 49.984-50.011 mm (1.9679-1.9689 inches) on all other models. Rod bearing undersizes are available.

To install crankshaft, reverse removal procedure. Tighten main bearing cap screws to 98-117 N·m (72-86 ft.-lbs.). Rolling torque necessary to turn crankshaft with pistons installed should not exceed 59 N·m (44 ft.-lbs.).

SLANZI

SLANZI OF NORTH AMERICA, INC.
P.O. Box 885
Minneapolis, MN 55440

Model	No. Cyls.	Bore	Stroke	Displ.
DVA515	1	86 mm (3.386 in.)	88 mm (3.465 in.)	511 cc (31.2 cu. in.)
DVA1030	2	86 mm (3.386 in.)	88 mm (3.465 in.)	1022 cc (62.4 cu. in.)

These engines are vertical cylinder, four-stroke, air-cooled direct injection diesels. Crankshaft rotation is counterclockwise at flywheel end.

MAINTENANCE

LUBRICATION

Recommended engine oil is SAE 20W-20 for temperatures below 0°C (32°F). When ambient temperatures will be above 0°C (32°F), use SAE 30 for winter operation or SAE 40 for summer operation. Only premium grade, heavy-duty, diesel engine oil should be used.

Under normal operating conditions, manufacturer recommends changing engine oil after every 200 hours of operation. When operating under severe duty conditions, such as high temperature and heavy load, oil should be changed after every 100 hours of operation. Oil should be drained while the engine is hot. Manufacturer recommends renewing the oil filter element after every 400 hours of operation. Crankcase capacity for DVA515 is 1.6 liters (1.75 quarts) without filter change and 1.75 liters (1.85 quarts) with filter change. Capacity for DVA1030 is 3.4 liters (3.6 quarts) without filter change and 3.55 liters (3.75 quarts) with filter change.

FUEL SYSTEM

FUEL FILTER AND BLEEDING. All engines are equipped with a renewable fuel filter. On DVA515 engines, filter is located inside the fuel tank behind the fuel outlet cover. On DVA1030 engines, fuel filter element is externally mounted on flywheel end of engine.

Manufacturer recommends renewing fuel filter element after every 200 hours of operation or sooner if engine indicates signs of fuel starvation (surging or loss of power). After renewing fuel filter, air must be bled from fuel system as follows:

To bleed air from fuel system, loosen bleeder screw (3–Fig. S1-1) at fuel injection pump. On DVA515 engine, allow gravity flow to force air out bleeder. Tighten bleed screw when fuel flow is free of air. On DVA1030, manually operate fuel transfer pump (2) until air-free fuel flows from bleeder valve, then retighten bleed screw.

If engine fails to start at this point, loosen high pressure fuel line (6) fitting at the injector. Set throttle at full speed position, then crank engine until fuel is discharged from loosened fuel line. Tighten fitting and start engine.

ENGINE SPEED ADJUSTMENT

The engine should be at normal operating temperature before adjusting engine speeds. Low and high idle (no-load) speeds are adjusted using throttle lever stop screws (1 and 2–Fig. S1-2) located on governor cover. Turning screw (1) clockwise will increase low idle speed and turning screw (2) counterclockwise will increase maximum

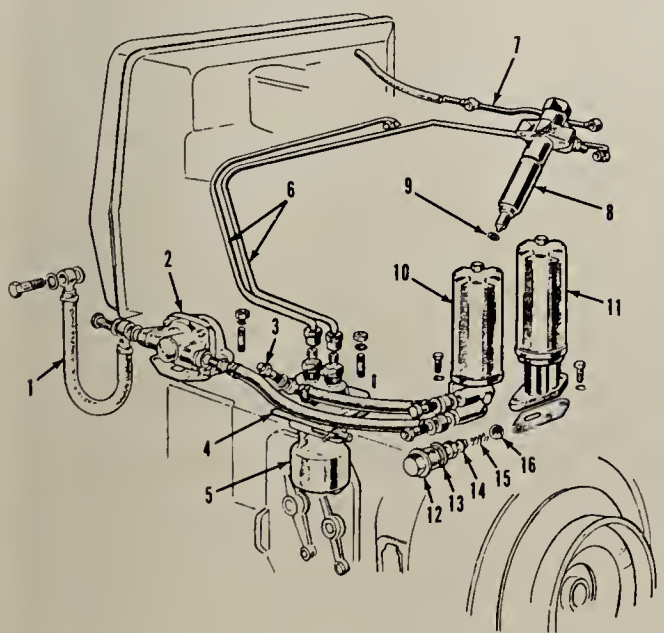


Fig. S1-1—View of fuel system, oil filter and oil pressure relief valve assembly for DVA1030. On DVA515, fuel filter is located in fuel tank and fuel transfer pump (2) is not used.

1. Fuel inlet line
2. Fuel transfer pump
3. Bleed screw
4. Shim gasket
5. Injection pump
6. High pressure injector lines
7. Fuel return line
8. Injector
9. Nozzle gasket
10. Fuel filter
11. Oil filter
12. Plug
13. Gasket
14. Oil pressure adjusting screw
15. Spring
16. Relief valve ball

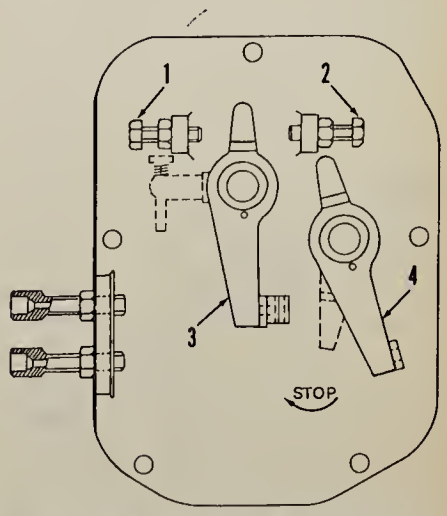


Fig. S1-2—Low and high speed adjusting screws are located on the governor cover.

1. Low speed screw
2. High speed screw
3. Throttle lever
4. Stop lever

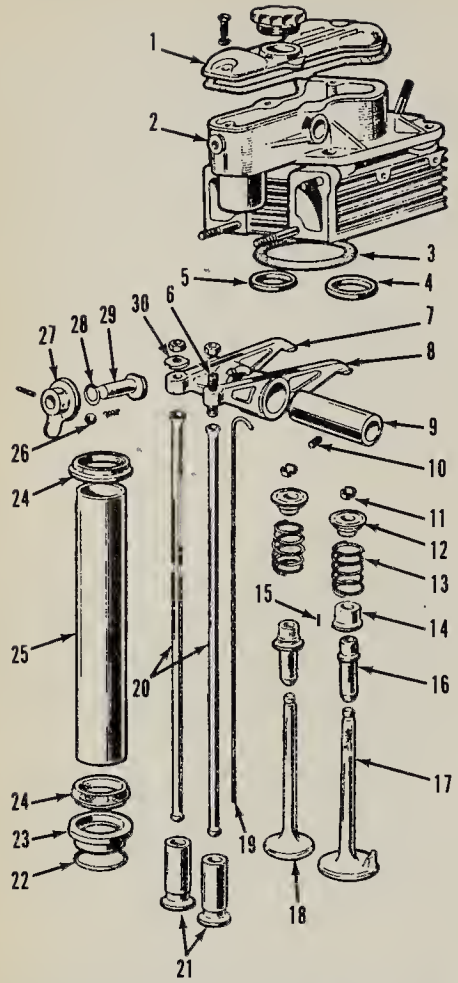


Fig. S1-3—Exploded view of cylinder head and valve system. Compression release mechanism is used on DVA515 engine.

1. Valve cover
2. Cylinder head
3. Gasket
4. Valve seat insert (intake)
5. Valve seat insert (exhaust)
6. Adjusting screw
7. Rocker arm (exhaust)
8. Rocker arm (intake)
9. Rocker arm shaft
10. Set screw
11. Valve keepers
12. Retainer
13. Valve spring
14. Cap nut (intake only)
15. Locating pin
16. Valve guide
17. Intake valve
18. Exhaust valve
19. Oil tube
20. Push rods
21. Cam followers
22. "O" ring
23. Bushing
24. Seals
25. Push rod tube
26. Detent ball
27. Compression release lever
28. "O" ring
29. Compression release shaft
30. Plate

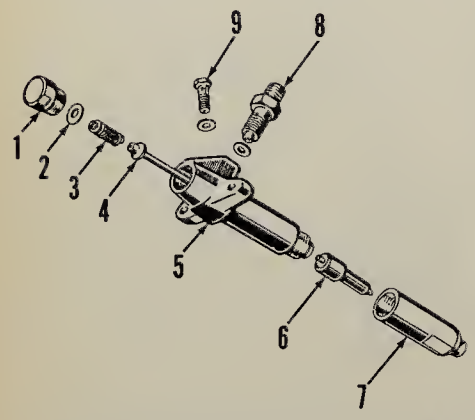


Fig. S1-4—Exploded view of fuel injector assembly.

1. Cap nut
2. Shim
3. Spring
4. Push rod
5. Injector body
6. Nozzle valve assy.
7. Nozzle holder nut
8. Fuel inlet fitting
9. Leak-off banjo bolt

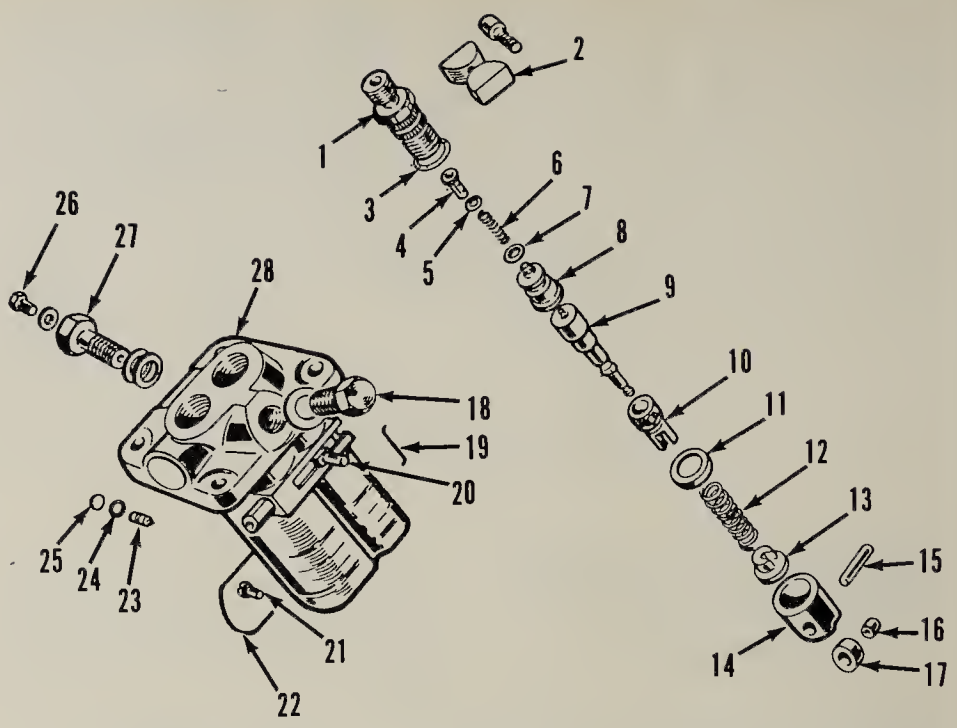


Fig. S1-5—Exploded view of BOSCH fuel injector pump. OMAP pump used on some engines is similar.

1. Delivery valve holder
2. Locks
3. Gasket
4. Spring guide
5. Shim
6. Spring
7. Gasket
8. Delivery valve
9. Pumping element
10. Sleeve
11. Retainer
12. Spring
13. Retainer
14. Tappet
15. Pin
16. Inner roller
17. Outer roller
18. Plug
19. Retainer
20. Control rack pin
21. Pin
22. Clip
23. Pin
24. Gasket
25. Plug
26. Bleed screw
27. Fuel inlet banjo bolt
28. Fuel pump body

governed speed. Adjust screws as needed to obtain specified governed speed as required for engine application. Do not exceeed maximum governed limit of 3200 rpm.

INJECTION PUMP TIMING

The injection pump is actuated by the engine camshaft. Injection timing is adjusted using shim gaskets (4–Fig. S1-1) between pump body and mounting surface of crankcase. Engines may be equipped with BOSCH or OMAP injection pump. Injection timing is the same for either pump.

To check injection timing, proceed as follows: Rotate crankshaft until "PM" mark on air shroud (13–Fig. S1-6) is aligned with "PMS" mark on flywheel cover (12) which indicates number 1 piston is at top dead center on compression stroke.

NOTE: It is possible to mount flywheel cover in four different positions, but only one can be used for timing purposes. If timing mark accuracy is in doubt, remove valve spring from a valve for number 1 cylinder. Allow valve to rest on top of piston, then use a dial indicator on valve stem end while turning crankshaft to double check TDC markings.

Disconnect injector line for number 1 cylinder from injection pump. Connect a fuel flow sight gage (special tool number 59.40.50) to injection pump delivery valve holder. If tool is not available, remove delivery valve holder (1–Fig. S1-5), spring (6) and valve (8), then reinstall delivery valve holder. Remove governor cover and position pump control rack at half speed setting. Maintain this setting during timing check. Connect fuel supply to pump. Note that fuel should flow from delivery valve holder at this time if delivery valve is removed. Rotate crankshaft counterclockwise approximately ½ turn, then turn slowly clockwise (normal direction of rotation) until first drop of fuel is observed at sight gage tool, or until fuel flow just stops if delivery valve is removed. At this point, beginning of injection occurs and "A1" mark on flywheel cover should be aligned with "PM" mark on air shroud. If timing marks are not aligned, increase pump mounting gasket thickness to retard timing or reduce shim gasket thickness to advance timing.

REPAIRS

TIGHTENING TORQUES

Refer to the following table for special tightening torques. All fasteners are metric.

Camshaft.....147 N·m (108 ft.-lbs.)

Connecting rod.....34-44 N·m (25-32 ft.-lbs.)
Cylinder head.....58-69 N·m (43-51 ft.-lbs.)
Flywheel.....216-255 N·m (160-195 ft.-lbs.)
Main bearing support – DVA1030.....49 N·m (36 ft.-lbs.)
Nozzle holder nuts.....20 N·m (15 ft.-lbs.)

VALVE ADJUSTMENT

To adjust valve clearance, first remove valve cover and rotate crankshaft until piston is at TDC on compression stroke (both rocker arms should be free to move). With engine cold, valve clearance should be 0.15 mm (0.006 inch) for intake and exhaust. Turn adjusting screw (6 – Fig. S1-3) until appropriate size feeler gage can be inserted between rocker arm and valve stem end. Tighten adjusting screw locknut and recheck adjustment.

After adjusting valves on first cylinder of DVA1030 engine, turn crankshaft one complete revolution and adjust valves on second cylinder.

CYLINDER HEAD AND VALVE SYSTEM

The cylinder head is equipped with renewable valve guides and valve seat inserts for intake and exhaust. Valve stem diameter is 7.963-7.972 mm (0.3135-0.3138 inch) for intake and 7.961-7.970 mm (0.3134-0.3138 inch) for exhaust. Inside diameter of valve guides should be 7.975-8.011 mm (0.3140-0.3145 inch). Desired valve stem clearance in guide is 0.003-0.048 mm (0.0001-0.0019 inch) for intake and 0.005-0.050 mm (0.0002-0.0020 inch) for exhaust. Use a suitable installing tool when pressing new guides into cylinder head to prevent damage to guide. Press in from top of head until guide shoulder bottoms. Guides are presized and should not require reaming if carefully installed.

Valve seat inserts should have an interference fit in cylinder head counterbore of 0.125-0.170 mm (0.005-0.007 inch). Chilling insert in dry ice prior to installation will ease assembly. When properly installed, valve seat should be recessed 0.15-0.30 mm (0.006-0.012 inch) below cylinder head surface. With valves installed, measure distance valve heads project from cylinder head surface. Valve protrusion should be 1.10-1.50 mm (0.043-0.059 inch). If protrusion is excessive, regrind valve seat. If protrusion is less than specified, renew valve seat.

Injector nozzle tip should extend 3.3-3.7 mm (0.130-0.146 inch) beyond cylinder head surface. Adjust nozzle position, if necessary, using shim gaskets between nozzle valve and bottom of cylinder head nozzle bore.

When reassembling cylinder head, be sure pin (15 – Fig. S1-3) is in place to locate cap nut (14) on intake valve. Be sure lubricating oil tube (19) is properly connected. Renew push rod tube seals (24) if necessary. Tighten cylinder head stud nuts evenly using a crossing pattern to 58-69 N·m (43-51 ft.-lbs.). Adjust valve clearance as previously outlined.

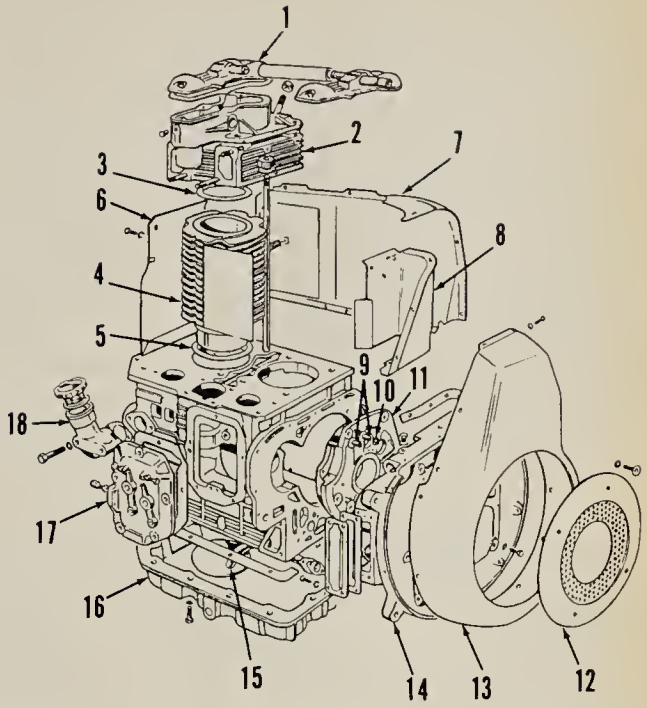


Fig. S1-6—Exploded view of DVA1030 crankcase assembly.

1. Valve cover
2. Cylinder head
3. Head gasket
4. Cylinder
5. Shim gasket
6. Air shield
7. Air shroud
8. Air shield
9. Oil tubes
10. Gasket
11. Main bearing support
12. Flywheel fan cover
13. Flywheel shroud
14. Crankcase end cover
15. Oil pickup
16. Oil pan
17. Governor cover
18. Oil filler

INJECTOR

REMOVE AND REINSTALL. Engines may be equipped with BOSCH or OMAP injector. Service procedures are identical for either injector. To remove injector, first clean injector, fuel lines and surrounding area of cylinder head. Disconnect return line and high pressure line and plug all openings. Unscrew retaining nuts and withdraw injector from cylinder head. Do not lose shim gasket between injector and cylinder head.

To reinstall injector, reverse the removal procedure. Tighten retaining nuts to 20 N·m (15 ft.-lbs.).

TESTING. A suitable test stand is required to check injector operation. Only clean, approved testing oil should be used to test injector.

WARNING: Fuel leaves the injector nozzle with sufficient force to penetrate the skin. When testing, keep yourself clear of nozzle spray.

Connect injector to tester and operate tester lever a few quick strokes to purge air from injector and to make sure nozzle valve is not stuck. When operating properly, injector nozzle will emit a buzzing sound and produce a uniform spray pattern.

Slowly operate tester lever while observing pressure gage reading. Opening pressure should be 19615-20595 kPa (2845-2985 psi). Opening pressure is adjusted by varying the thickness of shim (2 – Fig. S1-4).

Operate tester lever slowly to maintain pressure at 2000 kPa (300 psi) below opening pressure and check for leakage past nozzle valve. If a drop forms at nozzle tip within a 10 second period, nozzle valve is not seating and injector must be overhauled or renewed.

OVERHAUL. To disassemble injector, secure nozzle body (5 – Fig. S1-4) in a vise with nozzle tip facing upward. Remove nozzle holder nut (7) and withdraw nozzle valve (6). Invert nozzle body and remove plug (1), shim (2), spring (3) and rod (4).

Thoroughly clean all parts in a suitable solvent. Do not use steel wire brush or sharp metal tools to clean injector components. Make certain the nozzle valve needle slides freely in nozzle valve body. If needle sticks, reclean or renew nozzle valve assembly.

When reassembling injector, be sure all parts are clean and wet with diesel fuel. Recheck injector operation as outlined in TESTING section.

INJECTION PUMP

Engines may be equipped with a BOSCH or OMAP fuel injection pump.

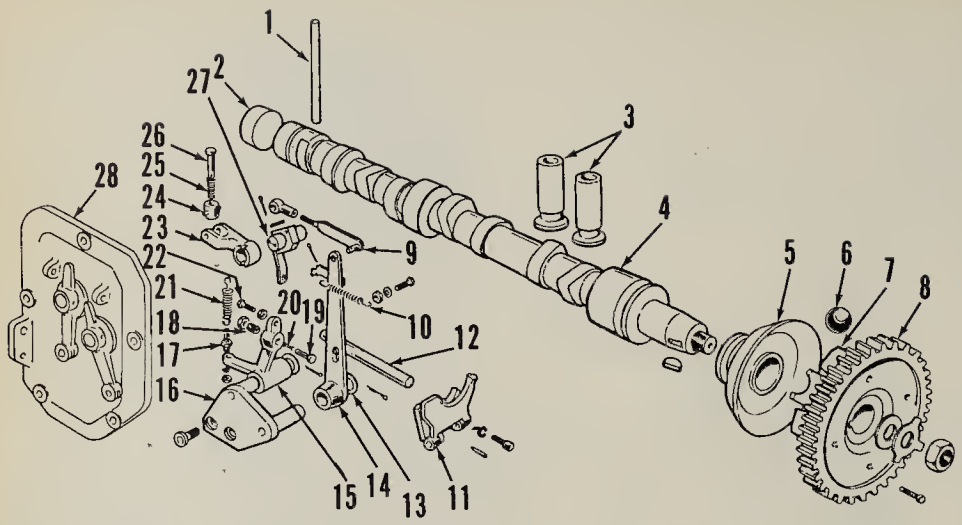


Fig. S1-7—Exploded view of camshaft, governor and governor linkage for DVA1030. DVA515 is similar.

1. Fuel pump push rod
2. Plug
3. Cam followers
4. Camshaft
5. Governor plate
6. Flyball
7. Collar
8. Camshaft gear.
9. Injection pump link
10. Governor spring
11. Pivot plate
12. Push rod
13. Washer
14. Governor arm
15. Pivot arm
16. Bracket
17. Adjusting screw
18. Adjusting screw
19. Pin
20. Spring
21. Spring
22. Adjusting screw
23. Throttle arm
24. Connector
25. Spring
26. Pin
27. Lever
28. Governor cover

Service procedures are similar for either pump.

To remove injection pump, disconnect fuel lines and immediately plug all openings to prevent entry of dirt. Remove retaining nuts and lift out injection pump. Be sure to note pump mounting shim gasket thickness for use in reassembly. Pump timing is adjusted by changing shim gasket thickness.

An exploded view of BOSCH pump is shown in Fig. S1-5. OMAP pump is similar. It is recommended that injection pump be tested and serviced only by a shop qualified in diesel fuel injection repair.

When reinstalling pump, assemble original thickness of mounting shim gasket and be sure to engage control rack pin (20) with governor linkage. If original mounting gasket thickness is unknown, required gasket thickness can be determined as follows: Rotate crankshaft until one lobe of injection pump camshaft is pointing downward. Measure distance from mounting surface of crankcase to base of camshaft lobe. Assemble gasket thickness necessary to obtain mounting dimension of 82.6-83.0 mm (3.252-3.268 inches) for BOSCH pump or 82.9-83.0 mm (3.264-3.268 inches) for OMAP pump. Check injection pump timing as outlined in MAINTENANCE section.

PISTON AND ROD UNIT

REMOVE AND REINSTALL. Piston and connecting rod may be removed after removing cylinder head, oil pan and oil pickup.

When reinstalling piston and rod, be sure depression in piston crown will be aligned with the injector nozzle tip. Make certain locating tabs of connecting rod bearing inserts engage notches in rod and cap and are located on the same side. Tighten connecting rod cap nuts to 34-44 N·m (25-32 ft.-lbs.).

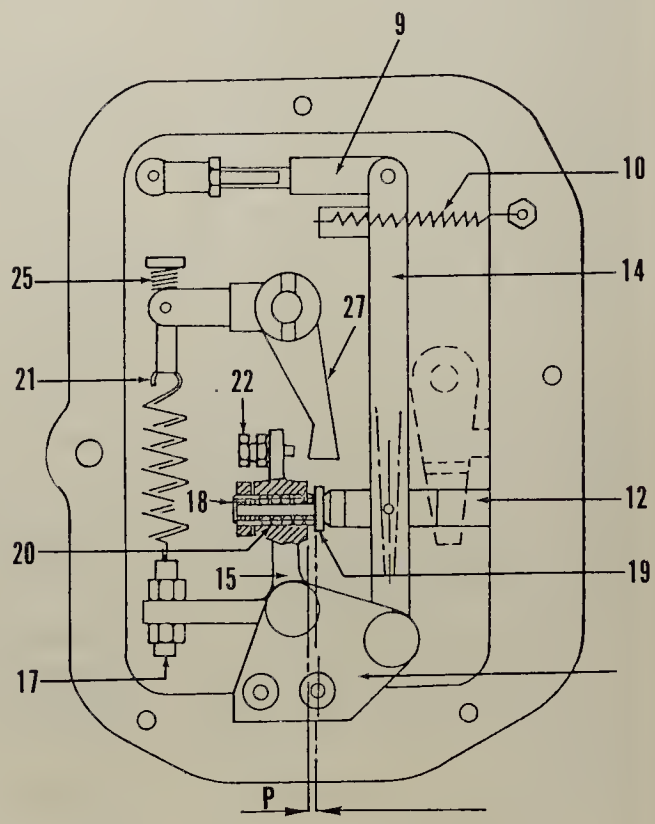


Fig. S1-8—Sectional view of governor linkage. Refer to Fig. S1-7 for component identification.

If connecting rod or piston was renewed, refer to CYLINDER section and measure piston height in cylinder.

PISTON, PIN AND RINGS

The piston is equipped with two compression rings and an oil control ring. Recommended piston ring end gap is 0.30-0.45 mm (0.012-0.018 inch) for compression rings and 0.25-0.40 mm (0.010-0.016 inch) for oil control ring. Standard piston diameter, measured at bottom of skirt perpendicular to piston pin, is 85.890-85.920 mm (3.3815-3.3826 inches).

Piston pin is retained in the piston by two snap rings. Piston pin diameter is 25.995-26.000 mm (1.0234-1.0236 inches) and piston pin bore is 25.991-26.000 mm (1.0233-1.0236 inches). Pin is a transition fit in piston bore. Initial fit when cold is 0.009 mm (0.0004 inch) interference to 0.005 mm (0.0002 inch) loose. Heating piston will ease removal and installation of pin.

CONNECTING ROD

The connecting rod small end is fitted with a renewable bushing. Bushing inside diameter should be 26.010-26.020 mm (1.0240-1.0244 inches). Recommended clearance between piston pin and bushing is 0.010-0.030 mm (0.0004-0.0012 inch).

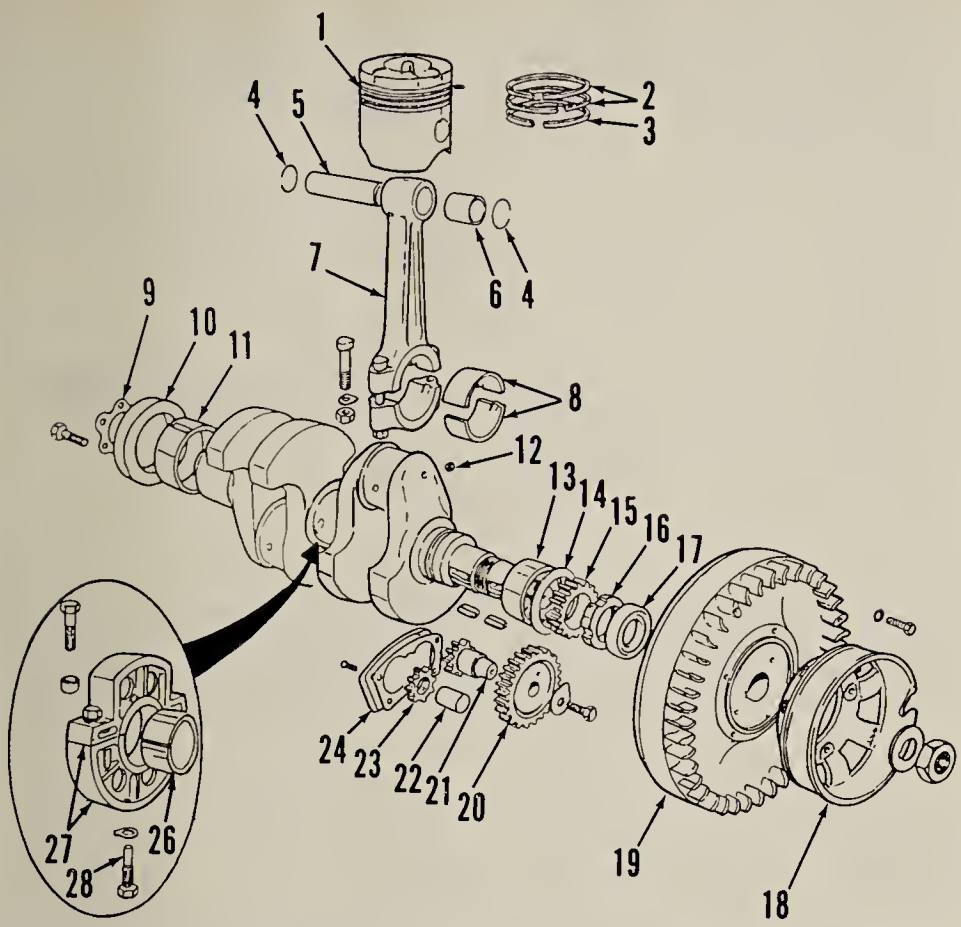


Fig. S1-9—Exploded view of crankshaft and oil pump assemblies. Center main bearing (26) and support (27) is used on DVA1030 engines.

1. Piston
2. Compression rings
3. Oil control ring
4. Retaining rings
5. Piston pin
6. Bushing
7. Connecting rod
8. Bearing
9. Washer
10. Oil seal
11. Main bearing
12. Plug
13. Main bearing
14. Thrust washer
15. Crankshaft gear
16. Nut
17. Oil seal
18. Starting pulley
19. Flywheel
20. Idler gear
21. Oil pump drive gear
22. Pin
23. Driven gear
24. Oil pump cover
26. Main bearing
27. Center main bearing support
28. Locating screw

A precision, insert type bearing is used in crankpin end of connecting rod. With rod bearing installed and rod cap nuts torqued to 34-44 N·m (25-32 ft.-lbs.), inside diameter of bearing should be 47.689-47.719 mm (1.8775-1.8786 inches). Recommended rod bearing clearance is 0.040-0.081 mm (0.0016-0.0032 inch). Bearings are available in standard size and undersizes.

CYLINDER

All engines are equipped with removable cylinders. Standard cylinder diameter is 86.000-86.020 mm (3.3858-3.3866 inches). Desired clearance between piston skirt and cylinder bore is 0.080-0.130 mm (0.003-0.005 inch). Cylinders that are damaged or excessively worn may be rebored for installation of 0.5 mm (0.020 inch) oversize piston and rings.

Piston height in cylinder is adjusted using shim gasket (5–Fig. S1-6) between bottom of cylinder and crankcase mounting surface. With piston at top dead center, top of piston must be 0.0-0.2 mm (0.0-0.008 inch) below top edge of cylinder.

GOVERNOR

All engines are equipped with a flyball type governor mounted on the camshaft drive gear. See Fig. S1-7. As the flyball (6) move in and out against plate (5), the fork (11) and push rod (12) transfer this movement through the governor linkage thereby moving injection pump control rack. The throttle control lever operates through lever (23), pivot arm (15) and spring (21) to control engine speed.

Injection pump maximum fuel delivery under load is adjusted by screw (22–Fig. S1-7 or S1-8). Turning screw one complete turn will change fuel delivery approximately 10 percent. Turning screw out (counterclockwise) will increase fuel flow.

Injection pump control rack is automatically placed in increased fuel delivery position for starting by spring (10).

Governor sensitivity (reaction to change in load) can be increased by turning adjusting screw (17) to increase tension on springs (21 and 25) and also by adjusting length of governor link (9).

The tendency for the governor to surge during speed changes is adjusted by turning set screw (18) to increase or decrease spring pin protrusion (P–Fig. S1-8). Increasing pin protrusion will reduce surging effect of governor. Dimension (P) must not exceed 0.5 mm (0.020 inch) measured without compressing spring.

For access to governor flyball assembly, remove flywheel shroud, flywheel, crankcase cover housing and camshaft gear.

CAMSHAFT AND CAM FOLLOWERS

To remove camshaft, first remove cylinder head, push rod tube and push rods, fuel injection pump and fuel transfer pump (DVA1030) and push rod (1–Fig. S1-7). Remove flywheel shroud, flywheel and crankcase cover housing. Using suitable tools, raise cam followers (3) away from camshaft and hold in that position. Remove camshaft gear (8) and governor plate (5). Unbolt and remove retainer plate (11), then carefully withdraw camshaft. Cam followers may be removed from the bottom after removing the oil pan. Be sure to identify cam followers so they can be reinstalled in their original positions.

The camshaft is supported in unbushed bores in the crankcase. A camshaft with oversize bearing journals is available if crankcase bores become excessively worn for standard size camshaft. Standard journal diameter for DVA515 is 35.950-35.975 mm (1.4153-1.4163 inches) for first journal and 23.959-23.980 mm (0.9432-0.9440 inch) for second journal. Crankcase bore diameter is 36.000-35.025 mm (1.4173-1.4183 inches) and 24.000-24.021 mm (0.9448-0.9456 inch). Clearance should be 0.025-0.075 mm (0.001-0.003 inch) for first journal and 0.020-0.062 mm (0.0008-0.0024 inch) for second journal. For DVA1030, standard journal diameter is 42.459-42.475 mm (1.6716-1.6722 inches) for first journal, 35.950-35.975 mm (1.4153-1.4163 inches) for second journal and 23.967-23.978 mm (0.9436-0.9440 inch) for third journal. Crankcase bore inner diameter is 42.500-42.525 mm (1.6732-1.6742 inches) for first bore, 36.000-36.025 mm (1.4173-1.4183 inches) for second bore and 24.000-24.021 mm (0.9449-0.9457 inch) for third bore. Clearance should be 0.025-0.066 mm (0.001-0.0026 inch) for first journal, 0.025-0.075 mm (0.001-0.003 inch) for second journal and

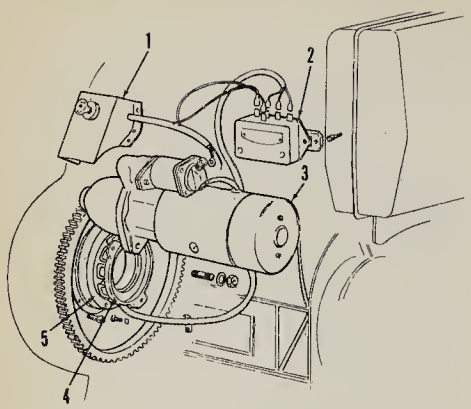


Fig. S1-10—On engines equipped with electric starting, an internally mounted alternator is located in the flywheel.

1. Key switch
2. Voltage regulator
3. Starter motor
4. Stator
5. Rotor

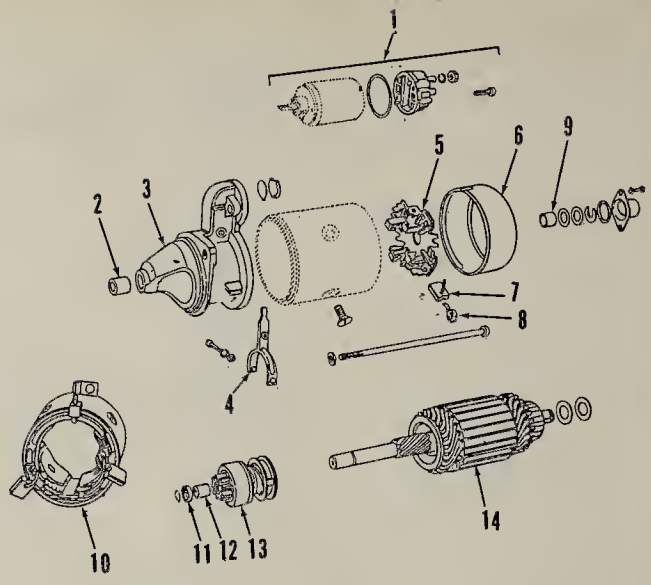


Fig. S1-11—Exploded view of starter motor used on engines equipped with electric starting.

1. Solenoid
2. Bushing
3. Drive cover
4. Lever
5. Brush frame
6. Cover
7. Brush
8. Spring
9. Bushing
10. Field coil & housing
11. Retainer
12. Bushing
13. Starter drive
14. Armature

0.022-0.054 mm (0.001-0.002 inch) for third journal.

Camshaft end play is controlled by retainer plate (11) and retaining groove in front of camshaft. Desired end play is 0.030-0.180 mm (0.0012-0.0071 inch).

To reinstall camshaft, reverse the removal procedure making certain the timing marks on camshaft gear, idler gear and crankshaft gear are aligned. Tighten camshaft gear retaining nut to 147 N·m (108 ft.-lbs.)

OIL PUMP

The oil pump gears (21 and 23—Fig. S1-9) are located in the crankcase cover housing. To remove pump gears, remove flywheel shroud and flywheel. Unbolt and remove cover housing. Remove idler gear (20), pump cover (24) and gears.

Inspect pump gears and housing for excessive wear or other damage. Renew as needed and reassemble by reversing the removal procedure.

The oil pressure relief valve is also located in the crankcase cover housing. Relief valve pressure setting may be adjusted with adjusting screw (14—Fig. S1-1).

CRANKSHAFT AND BEARINGS

The crankshaft rides in sleeve bearings (11 and 13—Fig. S1-9) located in crankcase housing and bearing support housing. DVA1030 engines are also equipped with a split center main bearing (26) mounted in bearing support (27).

To remove the crankshaft, remove flywheel, crankshaft pulley, oil pan, cylinder head, piston and connecting rod and crankcase cover housing. On DVA1030 engine, remove center main bearing support locating screw (28). On all engines, carefully withdraw crankshaft assembly out rear of crankcase.

On DVA515 engine, standard diameter of main journals is 44.946-44.962 mm (1.7695-1.7701 inches). Standard inner diameter of main bearings is 45.00-45.025 mm (1.7716-1.7726 inches). Desired operating clearance is 0.038-0.079 mm (0.0015-0.0031 inch). Standard and undersize main bearings are available. Replacement bearings must be bored to provide desired clearance. Standard crankpin diameter is 47.638-47.649 mm (1.8743-1.8759 inches) and desired rod bearing clearance is 0.040-0.081 mm (0.0016-0.0032 inch).

On DVA1030 engine, standard diameter of front main journal is 51.940-51.960 mm (2.0446-2.0454 inches), rear main journal diameter is 57.935-57.955 mm (2.2810-2.2818 inches) and center main journal diameter is 55.437-55.457 mm (2.1825-2.1833 inches). Desired main bearing clearance is 0.040-0.090 mm (0.0016-0.0035 inch) for front bearing, 0.045-0.095 mm (0.0018-0.0037 inch) for rear bearing and 0.043-0.093 mm (0.0017-0.0036 inch) for center bearing. Standard and undersize bearings are available. Front and rear replacement bearings must be bored to provide desired clearance. Crankpin standard diameter is 47.638-47.649 mm (1.8755-1.8759 inches) and desired rod bearing clearance is 0.040-0.081 mm (0.0016-0.0032 inch).

Crankshaft end play should be 0.050-0.150 mm (0.0020-0.0059 inch). End play is adjusted by changing thrust washer (14) thickness.

Reassembly is the reverse of disassembly. Be sure to renew crankshaft oil seals (10 and 17). Lubricate lip of seals with grease prior to reassembly. On DVA1030 engine, tighten center main bearing support cap screws to 49 N·m (36 ft.-lbs.). Make certain timing marks on camshaft gear, idler gear and crankshaft gear are aligned.

ELECTRICAL SYSTEM

On electric start engines, a flywheel mounted alternator is used to charge the battery. See Fig. S1-10. Electrical system is negative grounded on all engines. To avoid damage to charging system, do not disconnect battery cables or other electrical connections while engine is running. Refer to Fig. S1-11 for an exploded view of starter assembly.

SLANZI

Model	No. Cyls.	Bore	Stroke	Displ.
DVA1500	2	92 mm (3.622 in.)	88 mm (3.465 in.)	1755 cc (107 cu. in.)

The DVA1500 engine is a four-stroke, air-cooled, direct injection diesel with vertical inline cylinders. Crankshaft rotation is counterclockwise at flywheel end.

MAINTENANCE

LUBRICATION

Recommended engine oil is SAE 20W-20 for temperatures below 0°C (32°F). When ambient temperature will be above 0°C (32°F), use SAE 30 for winter operation or SAE 40 for summer operation. Only premium grade, heavy-duty, diesel engine oil meeting API CC specifications should be used.

Under normal operating conditions, manufacturer recommends changing engine oil after ever 200 hours of operation. When operating under severe duty conditions, such as high temperature and heavy load, oil should be changed after every 100 hours of operation. Oil should be drained while the engine is hot. Manufacturer recommends renewing the oil filter element after every 400 hours of operation. Crankcase capacity is approximately 4 liters (4.3 quarts) without filter change and 4.6 liters (4.9 quarts) with filter change.

The engine oil pressure relief valve assembly is located in the oil filter adapter housing (9 – Fig. S2-1). Pressure setting is adjustable using screw (4).

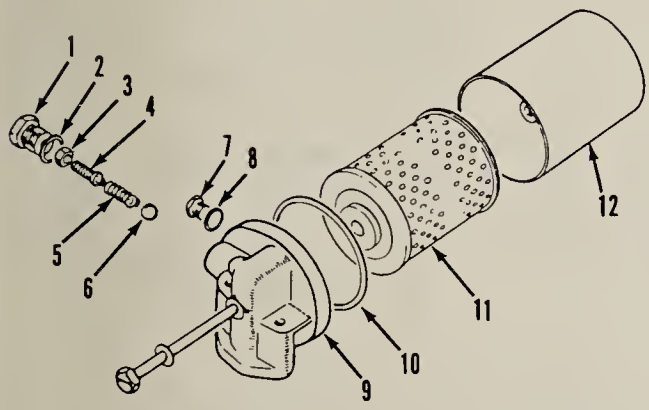


Fig. S2-1—Exploded view of engine oil filter assembly and oil pressure relief valve.

1. Plug
2. Washer
3. Nut
4. Adjusting screw
5. Spring
6. Ball
7. Plug
8. Washer
9. Adapter housing
10. Gasket
11. Oil filter element
12. Canister

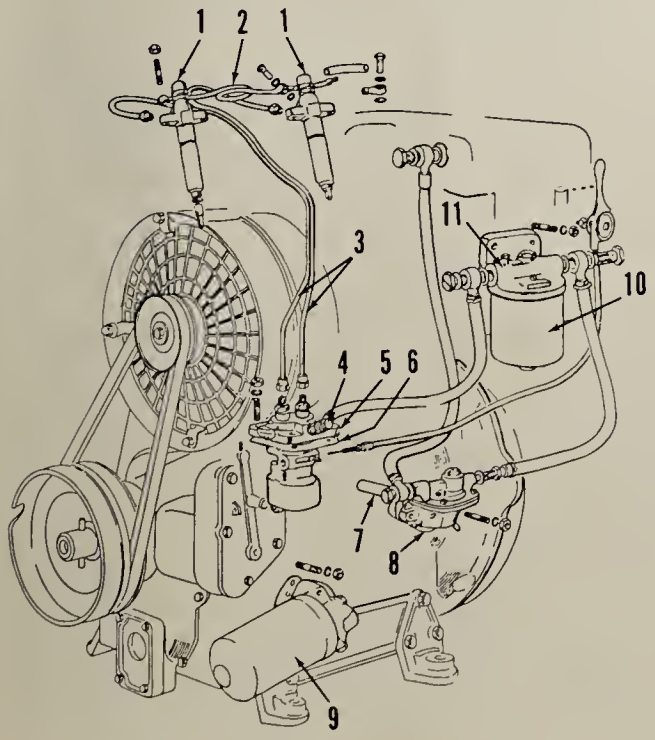


Fig. S2-2—View of fuel system components. Pump mounting gasket (6) is used to adjust injection timing.

1. Injector
2. Leak-off line
3. High pressure lines
4. Bleeder screw
5. Injection pump
6. Shim gasket
7. Push rod
8. Fuel transfer pump
9. Oil filter assy.
10. Fuel filter assy.
11. Bleeder screw

FUEL SYSTEM

FUEL FILTER AND BLEEDING. Manufacturer recommends renewing the fuel filter element after every 200 hours of operation. However, if engine indicates signs of fuel starvation (surging or loss of power), filter should be renewed regardless of hours of operation. After renewing fuel filter, air must be bled from the fuel system.

NOTE: A plastic filter screen is located in fuel transfer pump inlet. If engine fails to run properly after main fuel filter element has been renewed, inspect for plugged pump filter screen.

To bleed air from fuel system, loosen bleed screw (11 – Fig. S2-2) on fuel filter mounting base. Operate fuel transfer pump manually until air-free fuel flows from bleeder, then retighten screw. Loosen bleed screw (4) at injection pump fuel inlet. Operate fuel transfer pump until fuel flows from bleeder, then retighten screw. Continue to actuate transfer pump until resistance is felt to pressurize system.

If engine fails to start at this point, loosen high pressure fuel line (3) fittings at the injectors. Set throttle control in full speed position. Actuate decompression lever, then crank engine until fuel is discharged from loosened fuel lines. Retighten fittings and start engine.

ENGINE SPEED ADJUSTMENT

Engine should be at normal operating temperature when adjusting engine speeds. Low and high idle (no-load) speeds are adjusted using the throttle lever stop screws located on top of governor cover. If necessary, adjust screws to obtain specified governed speed as required for engine application.

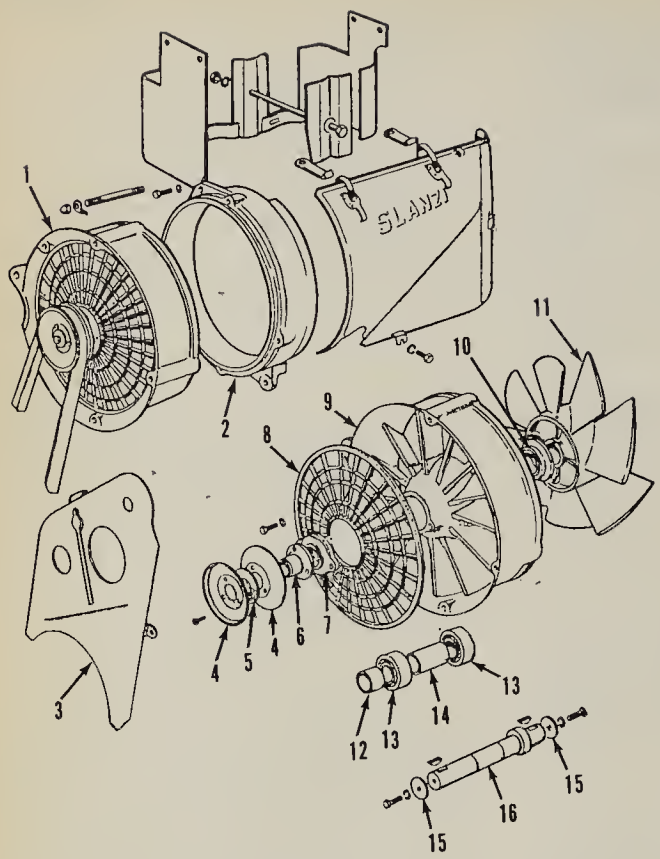


Fig. S2-3—Exploded view of axial flow engine cooling fan. Belt tension is adjusted by changing thickness of washer (5).

1. Fan assy.
2. Mounting housing
3. Belt guard
4. Pulley halves
5. Shim washer
6. Hub
7. Flange
8. Guard
9. Stator housing
10. Spacer
11. Fan
12. Spacer
13. Bearings
14. Spacer
15. Retaining washers
16. Fan shaft

Do not exceed maximum governed limit of 2750 rpm.

INJECTION PUMP TIMING

The injection pump is actuated by the injection pump camshaft. Injection timing is adjusted using shim gaskets (6—Fig. S2-2) between pump body and mounting surface of crankcase. Engine may be equipped with a BOSCH or OMAP injection pump. Injection timing is the same for either pump.

To check injection timing, top dead center of number 1 piston must first be determined. Rotate crankshaft until number 1 piston is on compression, then remove valve spring from a valve on number 1 cylinder to allow valve to rest on top of piston. Position a dial indicator against end of valve stem, then slowly turn crankshaft to locate piston TDC. Mark a reference mark on flywheel housing in alignment with arrow mark on flywheel. Reinstall valve spring.

Disconnect injector line for number 1 cylinder from injection pump. Connect a fuel flow sight gage (special tool 59.40.50) to number 1 discharge fitting on pump. If tool is not available, remove delivery valve holder (1—Fig. S2-6), spring (3) and delivery valve (5), then reinstall delivery valve holder. Remove governor cover and position pump control rack at half speed setting. Maintain this setting during timing check. Connect fuel supply to pump. Note that fuel should flow from delivery valve holder at this time if delivery valve is removed. Rotate flywheel clockwise approximately ½ turn, then turn slowly counterclockwise (normal direction of rotation) until first drop of fuel is observed at sight gage tool, or until fuel flow just stops if delivery valve is removed. At this point, beginning of injection occurs and "TDP" mark on flywheel should be aligned with reference mark made previously on flywheel housing. If timing marks are not aligned, remove injection pump and increase thickness of pump mounting gasket to retard timing or decrease thickness of gasket to advance timing.

REPAIRS

TIGHTENING TORQUES

Refer to the following table for special tightening torques. All fasteners are metric.

Connecting rod	61-65 N·m (45-48 ft.-lbs.)
Crankshaft counterweights	59-64 N·m (44-47 ft.-lbs.)
Cylinder head	83 N·m (61 ft.-lbs.)
Flywheel	236 N·m (174 ft.-lbs.)
Injector	20 N·m (15 ft.-lbs.)
Main bearing center support	45 N·m (33 ft.-lbs.)

COOLING FAN

An axial flow fan, belt driven by the crankshaft, provides the engine cooling air flow. Fan drive belt tension is ad-

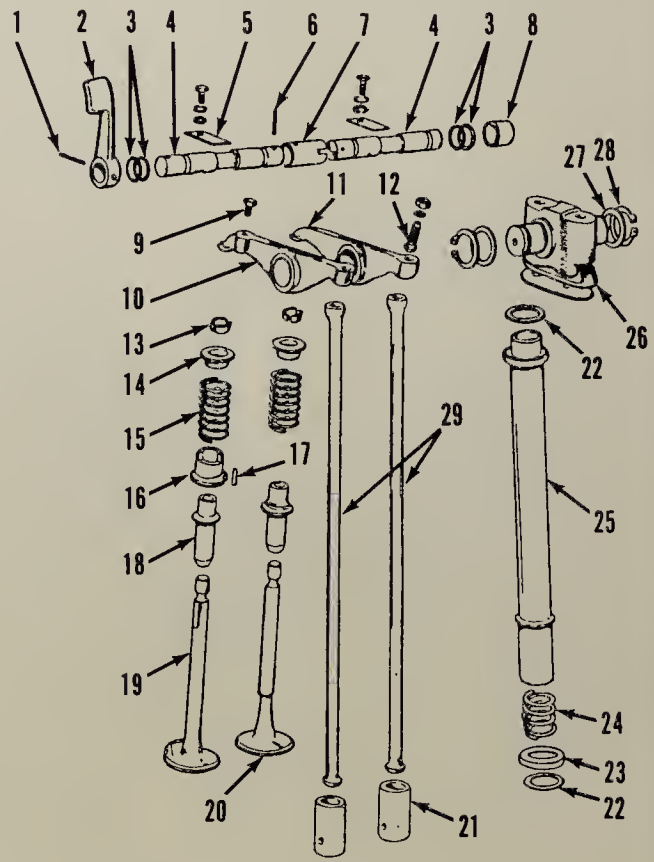


Fig. S2-4—Exploded view of valve assembly and compression release mechanism.

1. Pin
2. Compression release lever
3. Seals
4. Shaft
5. Spring clip
6. Pin
7. Connector
8. Spacer
9. Screw
10. Rocker arm (intake)
11. Rocker arm (exhaust)
12. Adjusting screw
13. Valve keepers
14. Retainer
15. Valve spring
16. Cap nut (intake only)
17. Locating pin
18. Valve guide
19. Intake valve
20. Exhaust valve
21. Cam followers
22. Seal
23. Cup washer
24. Spring
25. Push rod tube
26. Rocker arm support
27. Washer
28. Snap ring
29. Push rods

justed by changing thickness of washer (5 – Fig. S2-3) between fan pulley halves (4).

To disassemble fan, remove belt guard, fan pulley and drive belt. Unbolt and remove fan assembly (1) from mounting housing (2). Remove pulley hub (6), flange (7) and guard (8). Remove fan retaining screw and washer and withdraw fan (11) and spacer (10). Tap shaft (16), bearings (13) and spacers out of stator housing (9).

To reassemble, reverse the disassembly procedure.

VALVE ADJUSTMENT

To adjust valve clearance, first remove valve covers and rotate crankshaft until number 1 piston is at TDC on compression stroke (both rocker arms should be free to move). With engine cold, valve clearance should be 0.20 mm (0.008 inch) for intake and 0.25 mm (0.010 inch) for exhaust. Turn rocker arm adjusting screws (12 – Fig. S2-4) until appropriate size feeler gage can be inserted between rocker arm and valve stem end. Recheck adjustment after retightening adjusting screw locknut.

After adjusting valves on number 1 cylinder, turn crankshaft one complete revolution and adjust valves on second cylinder.

CYLINDER HEAD AND VALVE SYSTEM

To remove cylinder heads, first remove blower fan assembly and shrouds. Remove intake and exhaust manifolds. Disconnect fuel lines from injectors, then remove injectors. Remove cylinder head stud nuts and lift off cylinder heads. Remove valve covers with decompression shaft and rocker arm support (26 – Fig. S2-4) with rocker arms for access to valves.

Valve stem diameter is 8.960-8.975 mm (0.3527-0.3533 inch) for intake and exhaust valves. Valve guide inner diameter should be 8.976-9.006 mm (0.3534-0.3545 inch). Desired clearance of valve stem in guide is 0.010-0.046 mm (0.0004-0.0018 inch). Valve guides are renewable. When renewing guides, use a suitable installing tool to avoid damaging guides. Press guides into cylinder head until they bottom against their shoulders. Guides are presized and should not require reaming if carefully installed.

Renewable valve seat inserts are used for intake and exhaust. Inserts should have an interference fit of 0.125-0.170 mm (0.005-0.007 inch) in cylinder head counterbore. Chilling inserts with dry ice prior to installation will ease assembly. When properly installed, valve seat should be recessed 0.15-0.30 mm (0.006-0.012 inch) below surface of cylinder head. Position valves in cylinder and measure distance valve head extends from cylinder head surface. Both intake and exhaust valve should extend 0.90-1.25 mm (0.035-0.049 inch). If valve projection is excessive, regrind valve seat. If projection is less than specified, renew valve seat insert.

The injector nozzle tip should extend 3.0-3.5 mm (0.118-0.138 inch) beyond cylinder head surface. Adjust nozzle position, if necessary, using shim gaskets between injector nozzle and bottom of cylinder head nozzle bore.

When reassembling cylinder head, be sure locating pin (17) is in place to retain cap nut (16) on intake valve stem. Renew push rod tube oil seals (22) if necessary. Tighten cylinder head stud nuts evenly using a crossing pattern to 83 N·m (61 ft-lbs.). Adjust valve clearance as previously outlined.

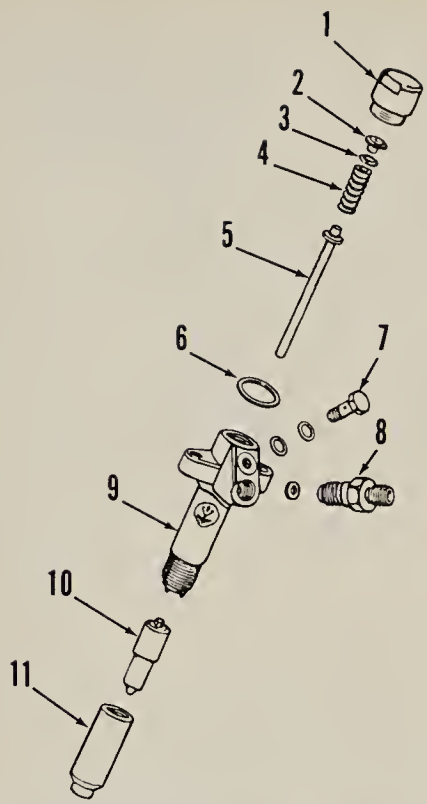


Fig. S2-5—Exploded view of fuel injector assembly.

1. Cap nut
2. Spring seat
3. Shim
4. Spring
5. Push rod
6. Gasket
7. Leak-off banjo bolt
8. Fuel inlet fitting
9. Injector body
10. Nozzle valve assy.
11. Nozzle holder nut

INJECTOR

REMOVE AND REINSTALL. Before removing injector, thoroughly clean injector, fuel lines and surrounding area. Disconnect fuel return line and high pressure line and plug all openings. Unscrew retaining nuts and withdraw injector from cylinder head.

To reinstall injector, reverse the removal procedure. Tighten retaining nuts to 20 N·m (15 ft.-lbs.).

TESTING. A suitable test stand is required to check injector operation. Only clean, approved testing oil should be used to test injector.

WARNING: Fuel leaves the injector nozzle with sufficient force to penetrate the skin. When testing, keep yourself clear of nozzle spray.

Connect injector to tester and operate tester lever a few quick strokes to purge air from injector and to make sure nozzle valve is not stuck. When operating properly, nozzle will emit a buzzing sound and produce a uniform spray pattern.

To check opening pressure, slowly operate tester lever while observing pressure gage reading. Opening pressure should be 19615-20595 kPa (2845-2985 psi). Opening pressure is adjusted by varying the thickness of shim (3 – Fig. S2-5).

Operate tester lever slowly to maintain pressure at 2000 kPa (300 psi) below opening pressure and check for leakage past nozzle valve seat. If a drop forms at nozzle tip within a 10 second period, nozzle valve is not seating and injector must be overhauled or renewed.

OVERHAUL. To disassemble injector, secure nozzle body (9 – Fig. S2-5) in a vise or holding fixture. Remove nozzle holder nut (11) and withdraw nozzle valve (10). Remove cap (1) and remove spring (2), shim (3), spring (4) and rod (5).

Thoroughly clean all parts in a suitable solvent. Do not use steel wire brush or sharp metal tools to clean injector components. Make certain the nozzle valve needle slides freely in nozzle valve body. If needle sticks, reclean or renew nozzle valve assembly.

When reassembling injector, be sure all parts are clean and wet with diesel fuel. Recheck injector operation as outlined in TESTING section.

INJECTION PUMP

Engine may be equipped with a BOSCH or OMAP fuel injection pump. Service procedures are similar for either pump. An exploded view of OMAP pump is shown in Fig. S2-6. It is recommended that the injection pump be tested and serviced only by a shop qualified in diesel fuel injection repair.

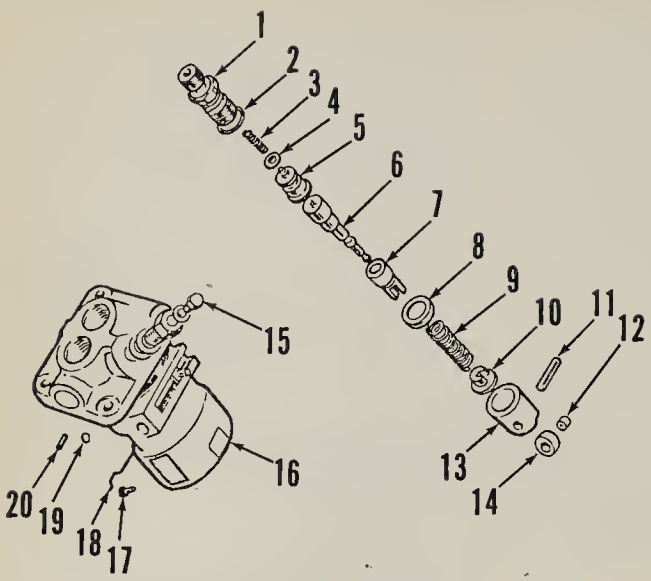


Fig. S2-6—Exploded view of OMAP fuel injection pump. BOSCH pump used on some engines is similar.

1. Delivery valve holder
2. Gasket
3. Spring
4. Gasket
5. Delivery valve
6. Pumping element
7. Bushing
8. Cup
9. Spring
10. Cup
11. Pin
12. Inner roller
13. Tappet
14. Outer roller
15. Bleed screw
16. Pump housing
17. Pin
18. Retainer
19. Plug
20. Pin

To remove injection pump, disconnect fuel lines and immediately plug all openings to prevent entry of dirt. Remove inspection cover from side of crankcase and disconnect governor rod from pump control rack pin. Remove pump mounting nuts and lift out pump assembly. Be sure to note pump mounting gasket thickness for use in reassembly.

When reinstalling injection pump, assemble original thickness of mounting shim gasket. Be sure to engage pump control rack pin with governor rod. If original mounting gasket thickness is unknown, required gasket thickness can be determined as follows: Rotate crankshaft until one lobe of injection pump camshaft is pointing downward. Measure distance from mounting surface of crankcase to base of camshaft lobe. Assemble gasket thickness necessary to obtain mounting dimension of 82.6-83.0 mm (3.252-3.268 inches) for BOSCH pump or 82.9-83.0 mm (3.264-3.268 inches) for OMAP pump. Check injection timing as outlined in MAINTENANCE section.

PISTON AND ROD UNIT

The piston and connecting rod may be removed after removing the cylinder head and oil pan. Number pistons and connecting rods as they are removed so they can be reinstalled in their original locations.

When reinstalling piston and rod, be sure piston is positioned so depression in piston crown will be aligned with the injector nozzle tip. Make certain locating tabs of connecting rod bearing inserts engage notches in rod and cap and are located on the same side. Tighten connecting rod cap nuts to 61-65 N·m (45-48 ft.-lbs.).

If connecting rod or piston was renewed, refer to CYLINDER section and measure piston height in cylinder.

PISTON, PIN AND RINGS

The piston is equipped with three compression rings and an oil control ring. Recommended piston ring end gap is 0.35-0.55 mm (0.014-0.022 inch) for compression rings and 0.25-0.40 mm (0.010-0.016 inch) for oil control ring. Standard piston diameter, measured at bottom of skirt perpendicular to piston pin, is 95.880-95.900 mm (3.7748-3.7756 inches). Piston and rings are available in standard size and 0.5 mm (0.020 inch) oversize.

Piston pin is retained in piston by two snap rings. Piston pin diameter is 27.995-28.000 mm (1.1021-1.1023 inches). Piston pin bore should be 27.991-28.000 mm (1.1019-1.1023 inches). Pin is a transition fit in piston bore. Initial pin fit when cold is 0.009 mm (0.0004 inch) interference to 0.005 mm (0.0002 inch) loose. Heating piston will ease removal and installation of pin.

CONNECTING ROD

The connecting rod small end is fitted with a renewable bushing. Bushing inside diameter should be 28.000-28.021 mm (1.1023-1.1031 inches). Recommended clearance between piston pin and bushing is 0.0-0.025 mm (0.0-0.001 inch).

A precision, insert type bearing is used in big end connecting rod. With bearing installed in rod and cap nuts torqued to 61-65 N·m (45-48 ft.-lbs.), inside diameter of bearing should be 57.175-57.201 mm (2.2510-2.2520 inches). Recommended clearance between crankpin and rod bearing is 0.051-0.090 mm (0.0020-0.0035 inch). Bearings are available in standard size and undersizes.

CYLINDER

Engine is equipped with removable cast iron cylinders. Standard cylinder bore is 96.000-96.020 mm (3.7795-3.7803 inches). Recommended clearance between piston skirt and cylinder is 0.100-0.140 mm (0.0039-0.0055 inch). Cylinders that are damaged or ex-

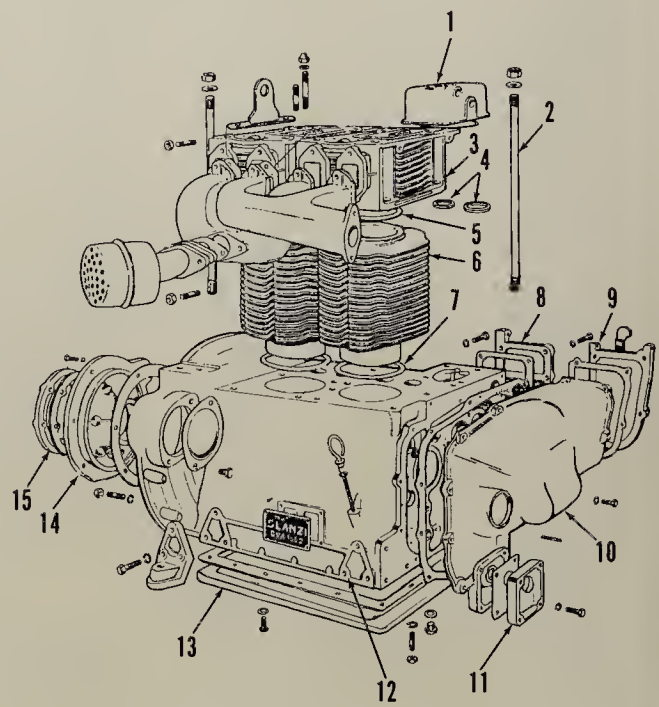


Fig. S2-7—Exploded view of crankcase assembly. Piston height in cylinder is adjusted using shim gaskets (7).

1. Valve cover
2. Cylinder stud
3. Cylinder head
4. Valve seat inserts
5. Head gasket
6. Cylinder
7. Shim gasket
8. Cover
9. Governor cover
10. Crankcase front cover
11. Cover
12. Crankcase
13. Oil pan
14. Main bearing support
15. Cover

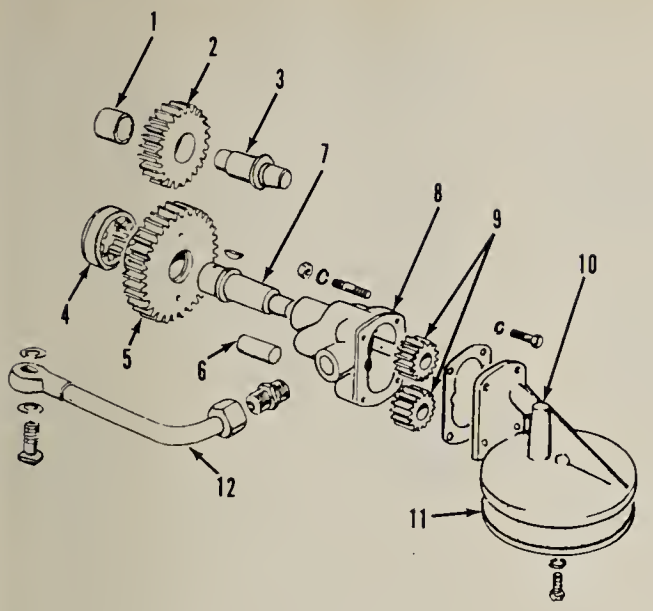


Fig. S2-8—Exploded view of engine oil pump assembly.

1. Bushing
2. Idler gear
3. Shaft
4. Bearing
5. Drive gear
6. Shaft
7. Pump drive shaft
8. Pump housing
9. Gears
10. Pump cover & oil pickup
11. Filter screen
12. Oil pressure tube

cessively worn may be rebored for installation of 0.5 mm (0.020 inch) oversize piston and rings.

Piston height in cylinder is adjusted using shim gasket (7–Fig. S2-7) between bottom of cylinder and crankcase mounting surface. With piston at top dead center, top of piston must be 0.0-0.2 mm (0.0-0.008 inch) below top edge of cylinder.

TIMING GEARS AND FRONT COVER

To gain access to timing gears, first remove belt guard, fan belt and engine cooling fan. Remove side cover (8–Fig. S2-7) and disconnect governor linkage from injection pump. Remove crankshaft front pulley, then unbolt and remove front cover (10) with governor linkage. Remove gears as needed. Be sure to align timing marks on gears when reassembling.

OIL PUMP

The gear type oil pump (Fig. S2-8) is mounted internally to front of crankcase. The pump is driven by the crankshaft gear through an idler gear (2).

To remove the oil pump, first drain the engine oil. Remove the oil pan and disconnect oil pressure tube (12). Remove timing gear cover as previously outlined. Remove pump drive gear (5), then unscrew pump mounting nuts and withdraw pump assembly.

Remove cap screws securing pump body (8) to oil pickup housing (10) and separate components. Inspect gears, shafts and pump body for damage or excessive wear and renew if necessary.

To reinstall oil pump, reverse the removal procedure.

GOVERNOR

The flyball type governor (Fig. S2-9) is located in the crankcase front cover. The governor is mounted on the front of camshaft gear. Camshaft rotation causes flyballs (4) to move in and out, depending upon engine speed, which moves governor cup (2) on bushing (1). The fork (9) transfers this motion through the governor linkage to the injection pump control rack to control injection pump fuel delivery.

To gain access to governor and governor linkage, remove governor side cover and crankcase front cover. Inspect all parts for wear and damage. Governor linkage must move freely to operate properly.

VALVE CAMSHAFT AND CAM FOLLOWERS

The camshaft is supported by unbushed bores in crankcase. A camshaft with oversize bearing journals is available if crankcase bores become excessively worn for standard size camshaft. Barrel type cam followers (7–Fig. S2-9) are used.

To remove camshaft, first remove cylinder head, push rods, push rod tubes and crankcase front cover as previously outlined. Lift out cam followers. Be sure to identify position of each cam follower as it is removed for correct reassembly.

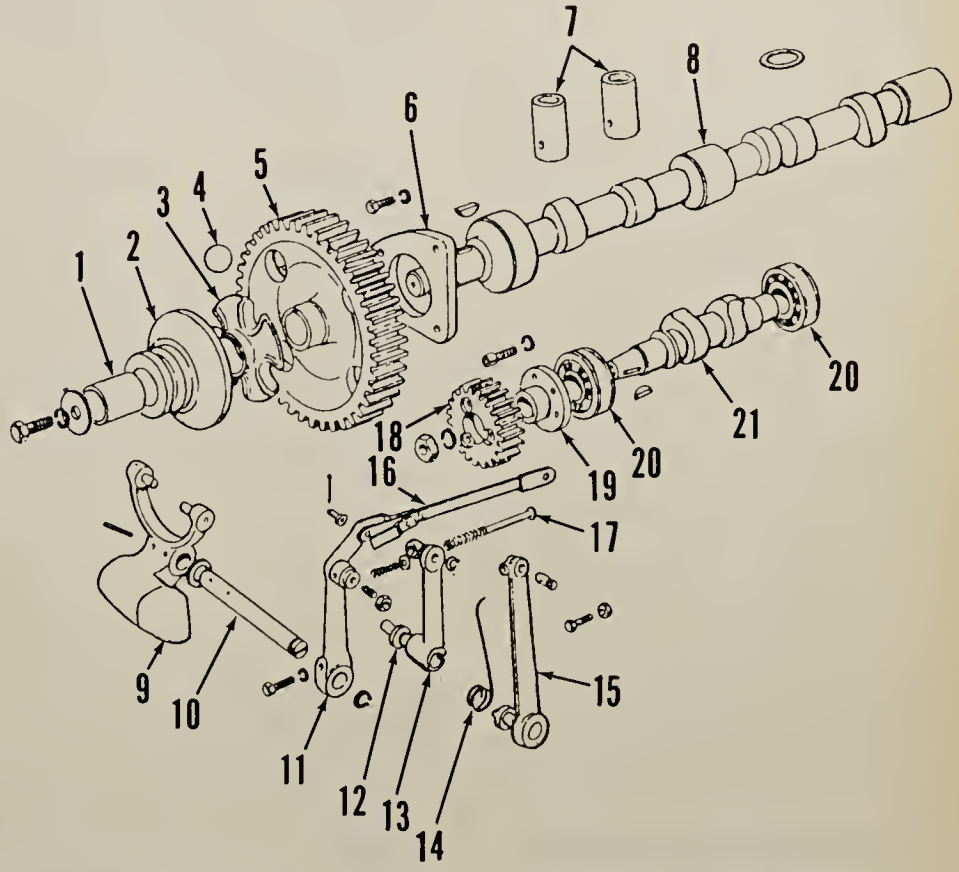


Fig. S2-9—Exploded view of valve camshaft (8), injection pump camshaft (21) and governor assembly.

1. Bushing
2. Governor cup
3. Collar
4. Flyball
5. Camshaft gear
6. Retainer plate
7. Cam followers
8. Valve camshaft
9. Governor fork
10. Pivot pin
11. Governor arm
12. Pin
13. Throttle arm
14. Spring
15. Throttle lever
16. Governor link
17. Pin
18. Gear
19. Hub
20. Bearings
21. Injection pump camshaft

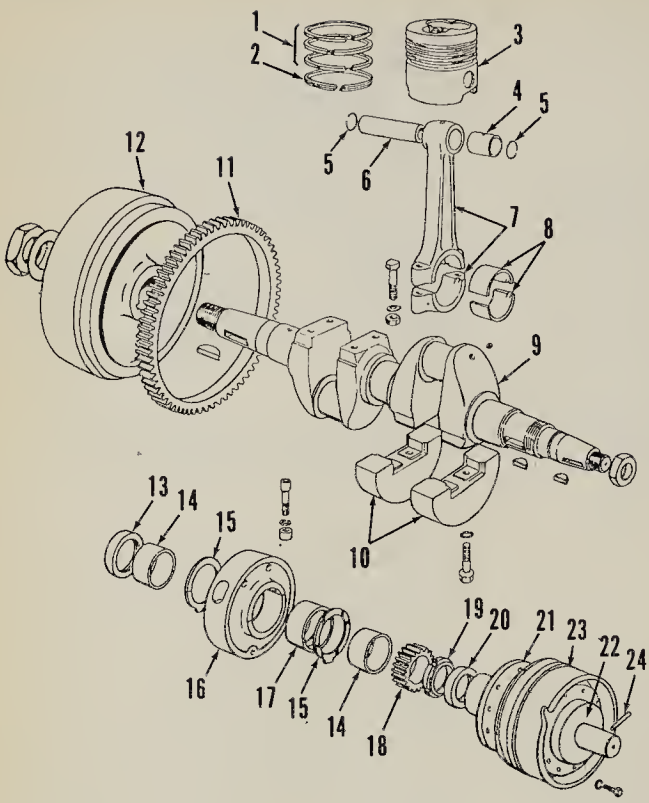


Fig. S2-10—Exploded view of piston and crankshaft assembly.

1. Compression rings
2. Oil control ring
3. Piston
4. Bushing
5. Retaining rings
6. Piston pin
7. Connecting rod
8. Rod bearing
9. Crankshaft
10. Counterweights
11. Ring gear
12. Flywheel
13. Oil seal
14. Main bearing
15. Thrust washers
16. Center bearing carrier
17. Main bearing
18. Crankshaft gear
19. Nut
20. Oil seal
21. Flange
22. Flange
23. Pulley
24. Pin

Remove governor retaining cap screw and remove governor assembly and camshaft gear. Remove camshaft retainer plate (6), then carefully withdraw camshaft.

Inspect bearing journals, cam lobes and cam followers for scoring, wear or other damage. Diameter of camshaft bearing journals should be 44.945-44.964 mm (1.7696-1.7702 inches) for front journal, 35.950-35.965 mm (1.4154-1.4159 inches) for center journal and 27.955-27.975 mm (1.1005-1.1013 inches) for rear journal. Diameter of crankcase bearing bores should be 45.000-45.025 mm (1.7716-1.7726 inches) for front bore, 36.000-36.025 mm (1.4173-1.4183 inches) for center bore and 28.000-28.021 mm (1.1023-1.1031 inches) for rear bore. Desired clearance between camshaft and support bores is 0.035-0.080 mm (0.0014-0.0031 inch) for front journal, 0.035-0.075 mm (0.0014-0.0030 inch) for second journal and 0.025-0.066 mm (0.0010-0.0026 inch) for rear journal.

Camshaft end play is controlled by retainer plate (6). Desired end play is 0.10-0.20 mm (0.004-0.008 inch).

To reinstall camshaft, reverse the removal procedure. Be sure to align timing marks on gears.

INJECTION PUMP CAMSHAFT

To remove the injection pump camshaft (21–Fig. S2-9), remove injection pump, fuel transfer pump and crankcase front cover. Remove drive gear (18) and hub (19), then remove camshaft (21) and bearings (20) from crankcase.

Inspect all parts and renew if necessary. To reinstall, reverse the removal procedure. Refer to INJECTION PUMP TIMING section to check and adjust injection timing.

CRANKSHAFT AND BEARINGS

The crankshaft rides in three sleeve type main bearings. Front bearing is located in crankcase bulkhead, rear bearing is mounted in crankcase rear cover. The center bearing is split and is contained in the two-piece center bearing support (16–Fig. S2-10).

To remove crankshaft, first remove the oil pan, flywheel and crankcase rear cover. Remove front pulley flange (22), then remove nut from front of crankshaft and withdraw front pulley (23) and flange (21) assembly. Unscrew retaining nut (19) and remove crankshaft gear (18). Remove connecting rod caps and push connecting rods and pistons up out of the way. Remove center bearing support retaining screws, then carefully withdraw crankshaft assembly from rear of crankcase. Separate center bearing support and bearing from crankshaft.

Standard diameter of main journals is 57.980-58.000 mm (2.2826-2.2834 inches) for front and rear journals and 62.970-62.983 mm (2.4793-2.4796 inches) for center journal. Standard main bearing inner diameter should be 58.045-58.060 mm (2.2852-2.2858 inches) for front and rear bearings and 63.031-63.055 mm (2.4815-2.4825 inches) for center bearing. Desired main bearing clearance is 0.045-0.080 mm (0.0018-0.0031 inch) for front and rear journals and 0.048-0.085 mm (0.019-0.0033 inch) for center journal. Standard and undersize main bearings are available. Replacement bearings must be bored to provide desired clearance.

Standard crankpin diameter is 57.111-57.124 mm (2.2484-2.2489 inches). Desired rod bearing operating clearance is 0.051-0.090 mm (0.002-0.0035 inch). Undersize bearings are available.

Crankshaft end play is controlled by thrust washers (15) located on either side of center main bearing support (30). Desired end play is 0.08-0.30 mm (0.003-0.012 inch). When installing thrust washers, be sure grooved side faces away from bearing support.

Inspect oil seals (13 and 20) and renew if necessary. Be sure to lubricate seal lips with grease prior to reassembly. To reinstall crankshaft, reverse the removal procedure. Tighten center bearing carrier screws to 45 N·m (33 ft.-lbs.), counterweight retaining screws to 59-64 N·m (44-47 ft.-lbs.) and flywheel nut to 236 N·m (174 ft.-lbs.).

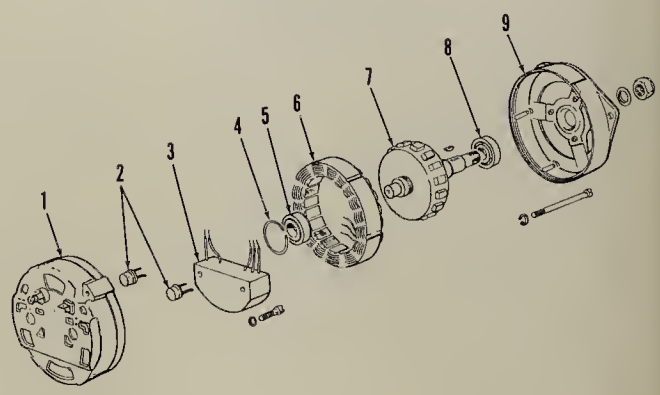


Fig. S2-11—Exploded view of alternator used on engines with electric starting.

1. End cover
2. Diodes
3. Regulator
4. Retainer
5. Bearing
6. Stator
7. Rotor
8. Bearing
9. Cover

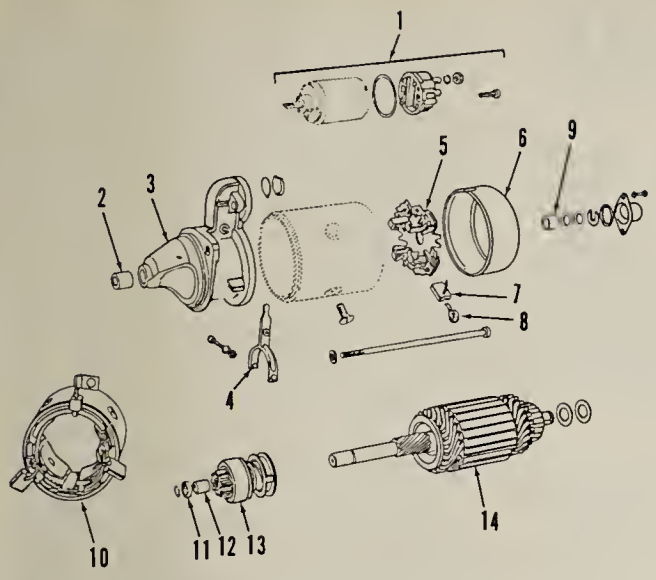


Fig. S2-12—Exploded view of electric starting motor.

1. Solenoid
2. Bushing
3. Drive end housing
4. Lever
5. Brush frame
6. Cover
7. Brush
8. Spring
9. Bushing
10. Field coil & housing
11. Retainer
12. Bushing
13. Starter drive
14. Armature

ELECTRICAL SYSTEM

The electrical system (if so equipped) is a 12-volt, negative ground system. The alternator is mounted to front of the engine and driven by the cooling fan drive belt. Belt tension is adjusted by changing thickness of washer (5–Fig. S2-3) between fan drive pulley halves (4). An integral, solid-state regulator (3–Fig. S2-11) controls alternator output.

A BOSCH or HARELLI starter motor is used on engines equipped with electric starting. See Fig. S2-12 for an exploded view of typical starter motor.

SLANZI

Model	No. Cyls.	Bore	Stroke	Displ.
DVA1550	3	86 mm (3.39 in.)	88 mm (3.46 in.)	1533 cc (93.5 cu. in.)
DVA1750	3	92 mm (3.62 in.)	88 mm (3.46 in.)	1755 cc (107 cu. in.)

These engines are four-stroke, air-cooled, direct injection diesel with vertical inline cylinders. Crankshaft rotation is counterclockwise at flywheel end. Number one cylinder is closest to crankshaft pulley end of engine. Firing order 1-3-2.

MAINTENANCE

LUBRICATION

Recommended engine oil is SAE 20W-20 for temperatures below 0°C (32°F). When ambient temperatures will be above 0°C (32°F), use SAE 30 for winter operation or SAE 40 for summer operation. Only premium grade, heavy-duty, diesel engine oil should be used.

Under normal operating conditions, manufacturer recommends changing engine oil after every 200 hours of operation. When operating under severe duty conditions, such as high temperature and heavy load, oil should be changed after every 100 hours. Oil should be drained while the engine is hot. Recommended oil filter renewal interval is every 400 hours of operation.

FUEL SYSTEM

FUEL FILTER AND BLEEDING. Manufacturer recommends renewing the fuel filter element after every 200 hours of operation. However, if engine indicates signs of fuel starvation (surging or loss of power), filter should be renewed regardless of hours of operation. After renewing fuel filter, air must be bled from the fuel system.

The fuel transfer pump also contains a plastic filter screen (1–Fig. S3-1) in the pump inlet. If engine fails to run properly after main fuel filter has been renewed, inspect for plugged pump filter screen as follows: Disconnect fuel lines from pump. Separate fuel inlet and outlet housing (4) from pump body to expose inlet valve (2) and filter screen. Remove and clean filter screen, then reinstall screen and reassemble pump.

To bleed air from fuel system, loosen bleeder screw on fuel filter mounting base. Operate fuel transfer pump until air-free fuel flows from bleeder, then retighten screw. If engine fails to start at this point, loosen high pressure fuel line fittings at the injectors. Set throttle control at full speed position. Crank engine with starter until fuel is discharged from loosened fuel lines. Retighten fittings and start engine.

ENGINE SPEED ADJUSTMENT

Engine should be at normal operating temperature when adjusting engine speed settings. Low and high idle (no-load) speeds are adjusted using throttle lever stop screws (1 and 3–Fig. S3-2) on governor cover. Turning screw (1) clockwise will decrease low speed setting and turning screw (3) clockwise will increase maximum governed speed. Adjust screws as required to obtain specified governed speeds depending on engine application. Do not exceed maximum governed limit of 3200 rpm.

Injection pump maximum fuel delivery is adjusted using stop lever screw (5). Turning screw clockwise will increase fuel delivery.

INJECTION PUMP TIMING

The injection pump is actuated by the injection pump camshaft (18–Fig. S3-9). Injection timing is adjusted by loosening timing gear (17) retaining screws and rotating camshaft within limits of retaining screw slots in timing gear.

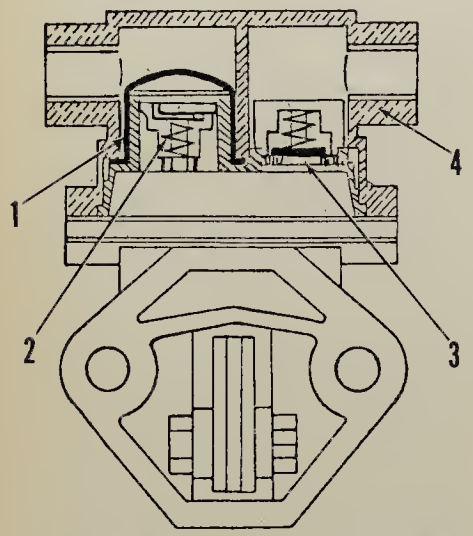


Fig. S3-1 – A plastic filter screen (1) is located in the inlet side of fuel transfer pump. If engine indicates signs of fuel starvation, check for plugged screen.

1. Filter screen
2. Inlet valve
3. Discharge valve
4. Valve housing

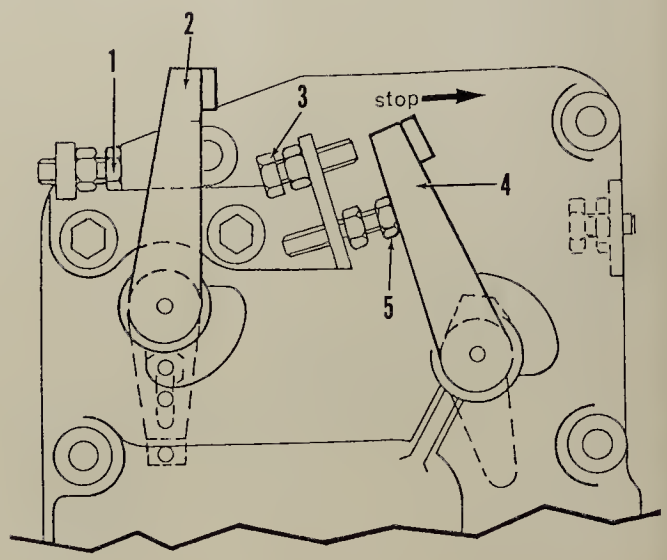


Fig. S3-2 – View of governor cover showing engine speed and maximum fuel delivery adjustment points.

1. Low idle adjusting screw
2. Throttle lever
3. Maximum speed adjusting screw
4. Stop lever
5. Fuel delivery adjusting screw

To check injection timing, rotate crankshaft pulley clockwise until number 1 piston is on compression and second mark (top dead center) on pulley is aligned with timing pin on crankcase front cover. Disconnect injector line for number 1 cylinder from injection pump. Connect a fuel flow sight gage (special tool number 59.40.50) to number 1 discharge fitting on pump. If tool is not available, remove delivery valve holder (1–Fig. S3-6), spring (6) and delivery valve (8), then reinstall delivery valve holder. Remove governor cover and position pump control rack at half speed setting. Maintain this setting during timing check. Connect fuel supply to pump. Note that fuel should flow from delivery valve holder at this time if delivery valve is removed. Rotate crankshaft pulley counterclockwise about ½ turn, then slowly turn clockwise (normal direction of rotation) until first drop of fuel is observed at sight gage tool, or until fuel flow just stops if delivery valve is removed. At this point, beginning of injection occurs and first mark on crankshaft pulley should be aligned with timing pin. If timing mark is not aligned, remove camshaft gear inspection cover from crankcase front cover. Loosen camshaft gear mounting screws, then rotate injection pump camshaft within limits of camshaft gear screw slots to obtain correct timing. Rotating camshaft clockwise will advance timing.

COOLING FAN

The engine cooling fan (6–Fig. S3-3) is mounted on the alternator and fan drive pulley (5). Fan belt tension should be checked every 100 hours of operation. Tension is adjusted by changing thickness of shim (11–Fig. S3-11) between crankshaft pulley halves on early production engines or by moving an idler pulley on late production engines.

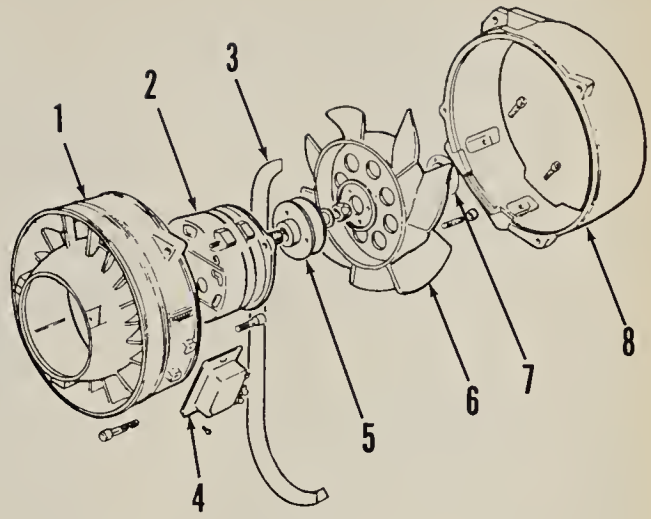


Fig. S3-3 – Exploded view of engine cooling fan.
1. Stator
2. Alternator
3. Drive belt
4. Warning light circuit
5. Pulley
6. Fan
7. Retainer plate
8. Fan housing

REPAIRS

TIGHTENING TORQUES

Refer to the following table for special tightening torques. All fasteners are metric.

Connecting rod	31-37 N·m (23-27 ft.-lbs.)
Crankshaft counterweight	58-64 N·m (43-47 ft.-lbs.)
Cylinder head	54-58 N·m (40-43 ft.-lbs.)
Flywheel	64-65 N·m (47-48 ft.-lbs.)
Injector	15-16 N·m (11-12 ft.-lbs.)
Main bearing supports	45-49 N·m (33-36 ft.-lbs.)

VALVE ADJUSTMENT

To adjust valve clearance, first remove valve covers. Rotate crankshaft until number 1 piston is at TDC on compression stroke (both rocker arms should be free to move). With engine cold, valve clearance should be 0.15 mm (0.006 inch) for intake and exhaust. Turn rocker arm adjusting screw (22–Fig. S3-4) until appropriate size feeler gage can be inserted between rocker arm and valve stem end. Tighten adjusting screw locknut and recheck adjustment.

Rotate crankshaft and adjust valves of each remaining cylinder in order of firing (1-3-2).

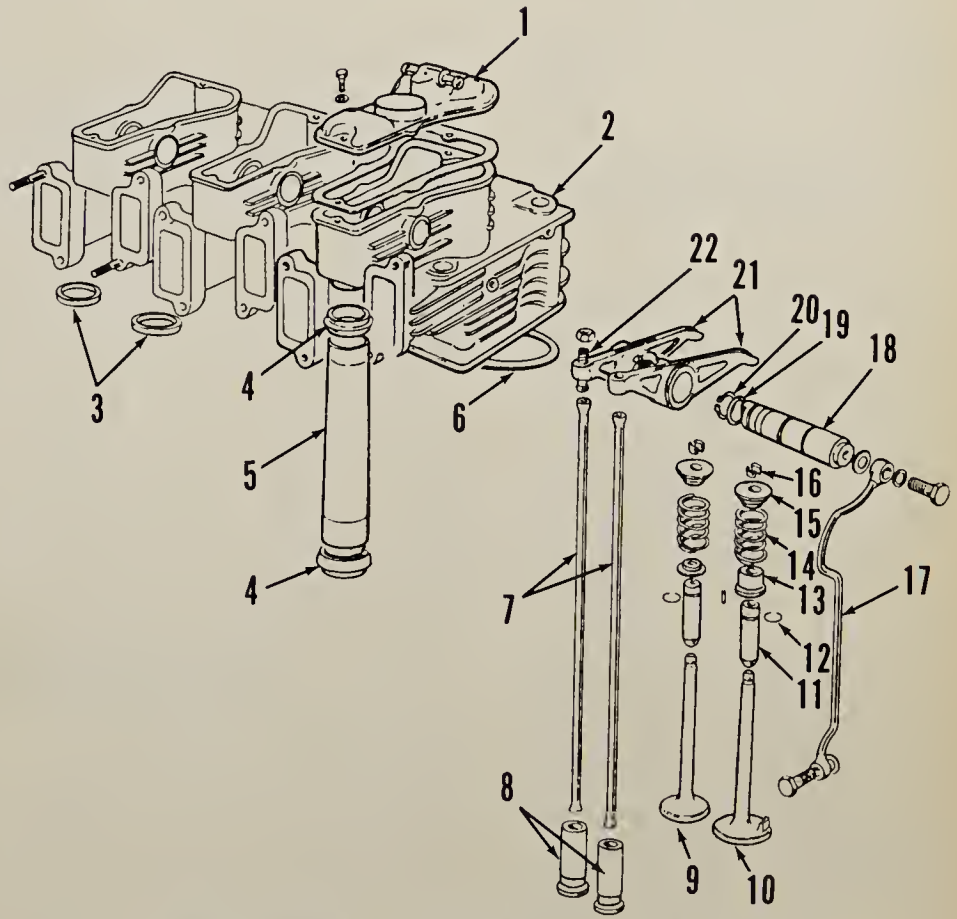


Fig. S3-4 – Exploded view of cylinder head and valve system.
1. Valve cover
2. Cylinder head
3. Valve seat inserts
4. Seals
5. Push rod tube
6. Head gasket
7. Push rods
8. Cam followers
9. Exhaust valve
10. Intake valve
11. Valve guide
12. Snap ring
13. Cap nut (intake only)
14. Valve spring
15. Retainer
16. Valve keepers
17. Oil tube
18. Rocker shaft
19. Gasket
20. Snap ring
21. Rocker arms
22. Adjusting screw

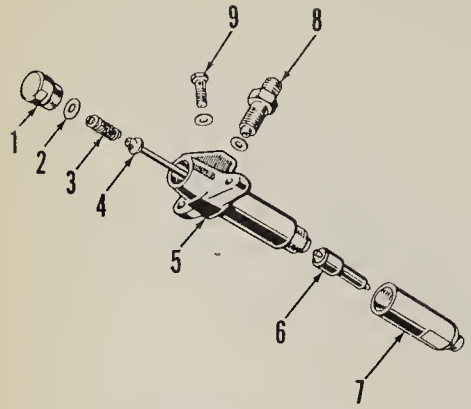


Fig. S3-5—Exploded view of injector used on DVA1550 engine.

1. Cap nut
2. Shim
3. Spring
4. Push rod
5. Injector body
6. Nozzle valve assy.
7. Nozzle holder nut
8. Fuel inlet fitting
9. Leak-off banjo bolt

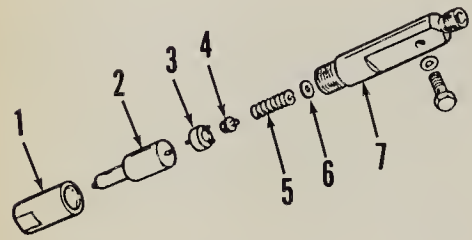


Fig. S3-5A—Exploded view of injector used on DVA1750 engine.

1. Nozzle holder nut
2. Nozzle valve
3. Spacer
4. Spring seat
5. Spring
6. Shim
7. Body

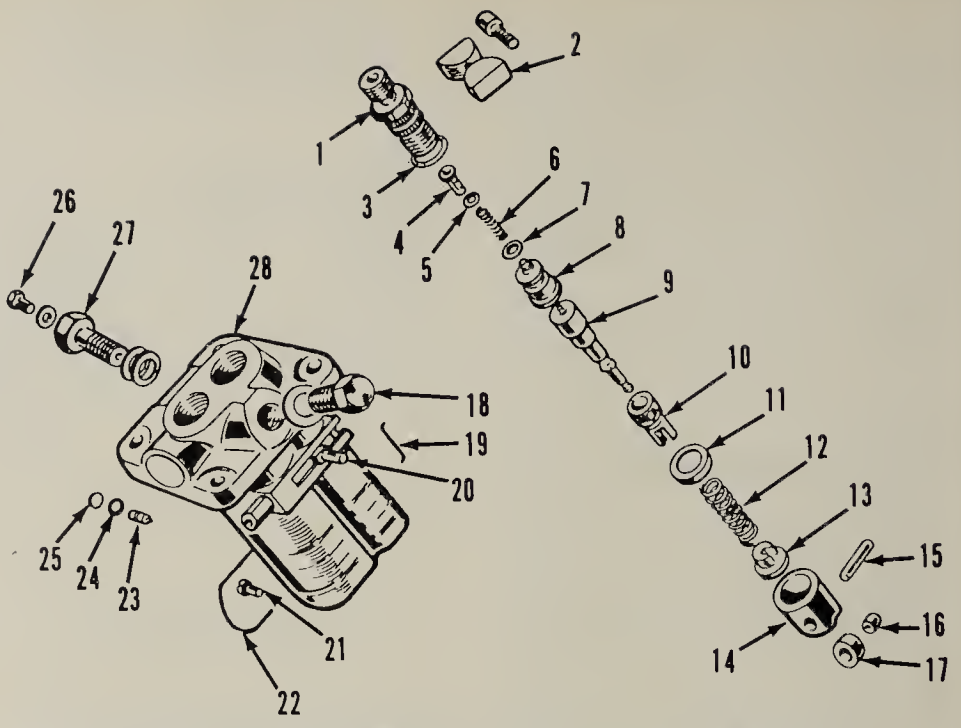


Fig. S3-6—Exploded view of BOSCH fuel injection pump used on all engines.

1. Delivery valve holder
2. Lock
3. Gasket
4. Spring guide
5. Shim
6. Spring
7. Gasket
8. Delivery valve
9. Pumping element
10. Sleeve
11. Gasket
12. Spring
13. Sleeve
14. Tappet
15. Pin
16. Inner roller
17. Outer roller
18. Plug
19. Retainer
20. Control rack pin
21. Screw
22. Retainer
23. Eccentric
24. Gasket
25. Plug
26. Bleed screw
27. Fuel inlet banjo bolt
28. Pump housing

CYLINDER HEADS AND VALVE SYSTEM

An individual cylinder head is used for each cylinder. To remove cylinder heads, remove blower fan and air shields, crankcase breather and tubes and intake and exhaust manifolds with air cleaner and muffler. Disconnect and remove injector high pressure and return fuel lines. Remove lubricating oil tubes from cylinder heads. Remove cylinder head stud nuts and lift off head. Remove valve cover, rocker arm shaft (18—Fig. S3-4) and rocker arms (21) for access to valves.

Valve stem diameter is 7.976-7.985 mm (0.3140-0.3144 inch) for intake and exhaust valves. Desired clearance of valve stem in guide is 0.015-0.039 mm (0.0006-0.0015 inch) for intake and 0.020- 0.044 mm (0.0008-0.0017 inch) for exhaust. Valve guides are renewable. When pressing in new guides, use suitable installing tool to prevent damage to guide. A snap ring (12) at top of guide determines installed height of guides. After installation, make certain valve stem move freely in guide. Guides are presized and should not require reaming if carefully installed.

Valve seat inserts are used for intake and exhaust. Inserts should have an interference fit of 0.130-0.180 mm (0.005-0.007 inch) in cylinder head counterbore. Chilling inserts in dry ice prior to installation will ease assembly. When properly installed, valve seat should be recessed 2.35-2.50 mm (0.093-0.098 inch) below cylinder head surface. With valves positioned in cylinder head, measure the distance valve head projects from head surface. Both intake and exhaust valves should project 0.90-1.10 mm (0.035-0.043 inch). If projection is excessive, regrind valve seat. If projection is less than specified, renew valve seat.

Injector nozzle tip should extend 2.3-2.7 mm (0.091-0.106 inch) beyond cylinder head surface. Adjust nozzle position, if necessary, using shim gaskets between nozzle valve and bottom of cylinder head nozzle bore.

If pistons or cylinders were renewed, check and adjust piston height in cylinder as outlined in CYLINDERS section before reinstalling head. If necessary, renew push rod tube seals. Tighten cylinder head stud nuts evenly using a crossing pattern to 54-58 N·m (40-43 ft.-lbs.). Complete installation by reversing removal procedure. Adjust valve clearance as previously outlined.

INJECTOR

REMOVE AND REINSTALL. Prior to removing injectors, thoroughly clean injectors, fuel lines and surrounding area. Disconnect and remove return lines and high pressure fuel lines and plug all openings to prevent entry of dirt. Unscrew retaining nuts and withdraw injector from cylinder head.

Make sure nozzle bore in cylinder head is clean before reinstalling injector. Use same thickness of seal washer to maintain nozzle tip protrusion in cylinder head. Tighten retaining nuts to 15-16 N·m (11-12 ft.-lbs.).

TESTING. A suitable test stand is required to check injector operation. Only clean, approved testing oil should be used to test injectors.

WARNING: Fuel leaves the injector nozzle wih sufficient force to penetrate the skin. When testing, keep yourself clear of nozzle spray.

Connect injector to tester and operate tester lever a few quick strokes to purge air from injector and to make sure nozzle valve is not stuck. When operating properly, injector nozzle will emit a buzzing sound and produce a uniform spray pattern.

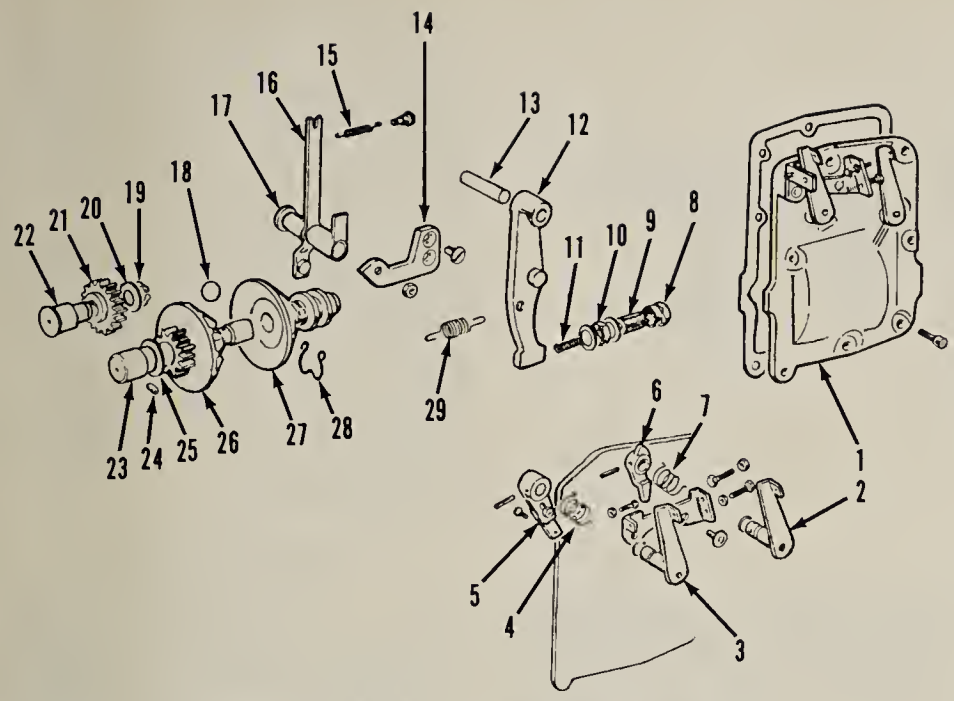


Fig. S3-7—Exploded view of governor and governor linkage.

1. Governor cover
2. Stop lever
3. Throttle lever
4. Spring
5. Lever
6. Cam
7. Spring
8. Plug
9. Adjusting screw
10. Nut
11. Spring
12. Pivot arm
13. Pin
14. Bracket
15. Spring
16. Governor lever
17. Eccentric pin
18. Flyball
19. Snap ring
20. Thrust washer
21. Idler gear
22. Idler shaft
23. Governor shaft
24. Set screw
25. Thrust washer
26. Collar
27. Governor cup
28. Spring
29. Spring

To check opening pressure, slowly operate tester lever while observing pressure gage reading. Opening pressure should be 19615-20595 kPa (2845-2985 psi). Opening pressure is adjusted by varying the thickness of shim (2—Fig. S3-5 or 6—Fig. S3-5A).

Operate tester lever slowly to maintain pressure at 2000 kPa (330 psi) below opening pressure and check for leakage past nozzle valve. If a drop forms at nozzle tip within a 10 second period, nozzle valve is not seating and injector must be overhauled or renewed.

OVERHAUL. To disassemble DVA1550 injector, refer to Fig. S3-5 and proceed as follows: Secure nozzle body (5) in a vise, then remove nozzle holder (7) and nozzle valve (6). Remove end cap (1) and withdraw shim (2), spring (3) and push rod (4).

To disassemble DVA1750 injector, refer to Fig. S3-5A and proceed as follows: Secure injector body (7) in a vise or holding fixture, then remove nozzle holder nut (1), nozzle valve (2), spacer (3), spring seat (4), spring (5) and shim (6).

NOTE: When disassembling more than one injector, keep parts separated as they should not be interchanged.

Thoroughly clean all parts in a suitable solvent. Do not use steel wire brush or sharp metal tools to clean injector components. Make certain nozzle needle slides freely in nozzle valve seat. If needle sticks, reclean or renew nozzle valve assembly.

When reassembling injector, be sure all parts are clean and wet with diesel fuel. Recheck injector operation as outlined in TESTING section.

INJECTION PUMP

To remove injection pump, disconnect fuel lines and immediately plug all openings to prevent entry of dirt. Remove retaining nuts and lift out injection pump.

An exploded view of injection pump is shown in Fig. S3-6. It is recommended that injection pump be tested and serviced only by a shop qualified in diesel fuel injection repair.

To reinstall injection pump, reverse the removal procedure. Note that pump mounting gasket thickness will affect pump timing. To determine correct gasket thickness, rotate crankshaft until one lobe of injection pump camshaft is pointing downward. Measure the distance from mounting surface of crankcase to base of camshaft lobe. Assemble gasket thickness necessary to obtain mounting dimension of 82.6-83.0 mm (3.252-3.267 inches). Check injection pump timing as outlined in MAINTENANCE section.

GOVERNOR

The flyball type governor is located in the side of crankcase behind the governor cover assembly (1—Fig. S3-7). The governor is driven by a gear on the injection pump camshaft via an idler gear (21). Governor rotation causes flyballs (18) to move in and out which moves the

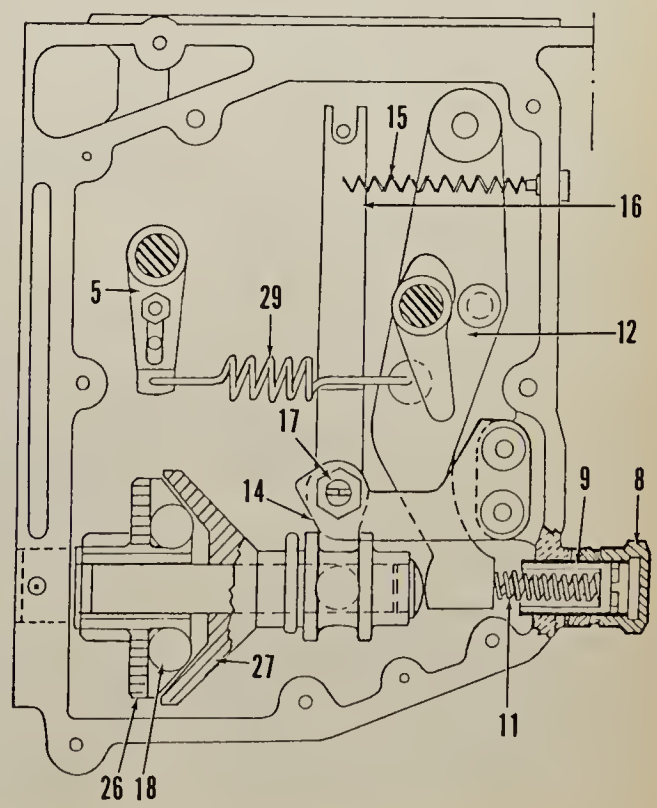


Fig. S3-7A—Sectional view of governor assembly. Refer to Fig. S3-7 for component indentification.

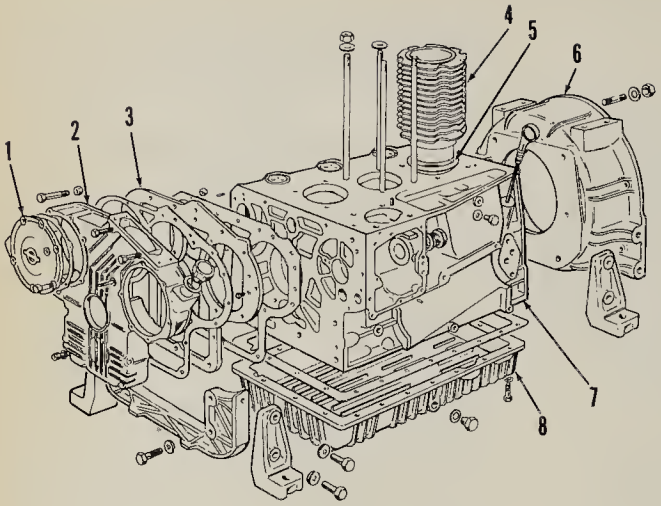


Fig. S3-8 – Exploded view of crankcase and front cover assembly.

1. Cover plate
2. Front cover
3. Plate
4. Cylinder
5. Shim gasket
6. Flywheel housing
7. Crankcase
8. Oil pan

governor cup (27). The cup movement is transferred through the governor linkage to actuate injection pump control rack.

Remove governor cover (1) to gain access to governor flyball assembly. Remove set screw (24) securing governor shaft, then remove governor linkage and flyball assembly.

Inspect all parts for wear or other damage and renew if necessary. Be sure all parts move freely. Reinstall by reversing the removal procedure.

To adjust governor linkage, proceed as follows: To reduce tendency of governor to surge during changes in speed or load, remove plug (8 – Fig. S3-7 or S3-7A) and turn adjusting screw (9) inward to increase spring (11) projection. Note that this adjustment will also alter engine speed adjustment. If governor still does not operate smoothly, loosen nut and rotate eccentric pin (17) to move axis of pin upward slightly.

To increase governor sensitivity in reacting to change in load (speed droop), loosen nut and shorten lever (5) to increase tension on spring (29).

Engine idle speed is adjusted by turning stop screw (1 – Fig. S3-2). Maximum governed speed is adjusted using screw (3). Maximum injection pump fuel delivery is adjusted with screw (5). Turning screw inward (clockwise) increases maximum fuel delivery.

Injection pump control rack is automatically set in increased fuel delivery position for starting by tension of spring (15 – Fig. S3-7).

PISTON AND ROD UNIT

Pistons and connecting rods may be removed after first removing cylinder heads, oil pan and oil pickup. Be sure to number piston and rod units as they are removed so units can be reinstalled in their original position.

When reinstalling piston and rod, be sure to position piston so depression in piston crown will be aligned with injector nozzle tip when cylinder head is installed. Make certain locating tabs of connecting rod bearing insert engage notches in rod and cap and are located on the same side. Tighten connecting rod cap nuts to 31-37 N·m (23-27 ft.-lbs.).

If connecting rod or piston was renewed, refer to CYLINDER section and measure piston height in cylinder.

PISTON, PIN AND RINGS

The piston is equipped with two compression rings and an oil control ring. Standard piston diameter, measured at bottom of skirt perpendicular to piston pin, is 85.890-85.920 mm (3.3815-3.3827 inches) for DVA1550 and 91.885-91.905 mm (3.6175-3.6183 inches) for DVA1750. Recommended piston ring end gap for all engines is 0.40-0.65 mm (0.016-0.026 inch) for the compression rings and 0.25-0.45 mm (0.010-0.018 inch) for the oil control ring.

Piston pin is retained in piston by two snap rings. Pin diameter is 25.995-26.000 mm (1.0234-1.0236 inches) and piston pin bore is 25.991-26.000 mm (1.0233-1.0236 inches). Pin is a transition fit in piston bore. Initial fit when cold is 0.009 mm (0.0003 inch) interference to 0.005 mm (0.0002 inch) loose. Heating piston will ease removal and installation of pin.

CONNECTING ROD

The connecting rod small end is fitted with a renewable bushing. Bushing inside diameter should be 26.010-26.020 mm (1.0240-0.0244 inches). Recommended clearance between piston pin and bushing is 0.010-0.030 mm (0.0004-0.0012 inch).

A precision, insert type bearing is used in crankpin end of connecting rod. With rod bearing installed and rod cap nuts tightened to 31-37 N·m (23-27 ft.-lbs.), inside diameter of bearing should be 53.073-53.108 mm (2.0895-2.0909 inches). Recommended rod bearing clearance is 0.038-0.086 mm (0.0015-0.0034 inch). Bearings are available in standard size and undersizes.

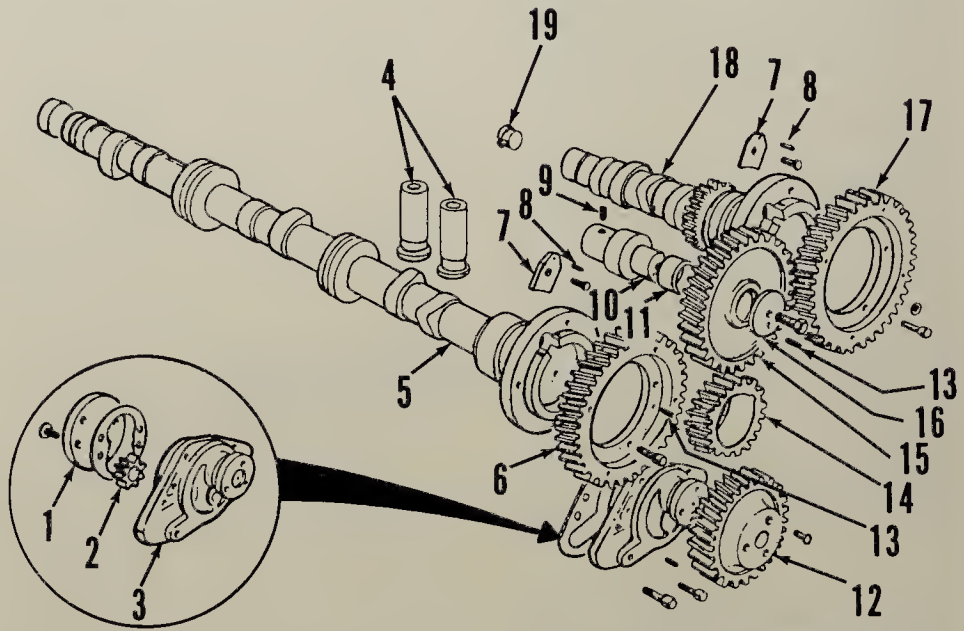


Fig. S3-9 – View of timing gears, valve camshaft, fuel injection camshaft and oil pump assembly.

1. Cover
2. Pump cover
3. Oil pump housing
4. Cam followers
5. Valve camshaft
6. Gear
7. Retainer plate
8. Locating pin
9. Set screw
10. Idler shaft
11. Bushing
12. Oil pump gear
13. Locating pin
14. Crankshaft gear
15. Idler gear
16. Retaining plate
17. Gear
18. Fuel injection camshaft
19. Plug

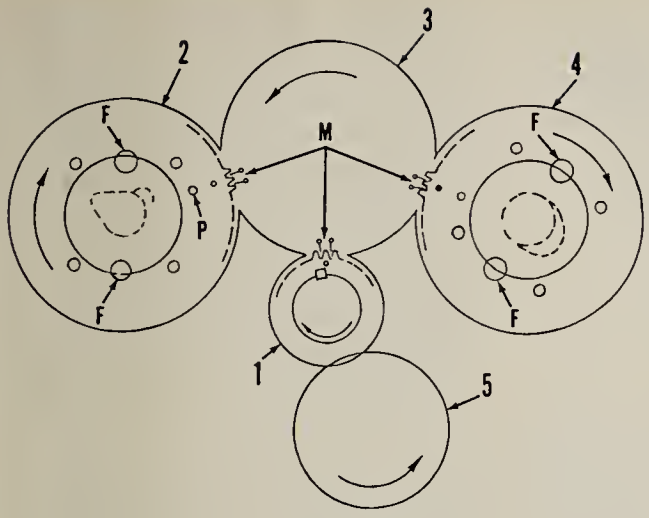


Fig. S3-10 – When reinstalling timing geers, timing merks (M) must be eligned as shown. Refer to text.

1. Crankshaft gear
2. Valve camshaft gear
3. Idler gear
4. Injection pump camshaft gear
5. Oil pump gear

CYLINDER

Engines are equipped with removable, cast iron cylinders. Standard cylinder bore is 85.980-86.000 mm (3.3850-3.3858 inches) for DVA1550 and 92.000-92.020 mm (3.6220-3.6228 inches) for DVA1750. Desired piston skirt clearance in cylinder is 0.080-0.120 mm (0.003-0.005 inch) for DVA1550 and 0.095-0.135 mm (0.004-0.005 inch) for DVA1750. If cylinder bore is damaged or excessively worn, cylinder may be rebored for installation of 0.5 mm (0.020 inch) oversize piston and rings.

Piston height in cylinder is adjusted by varying shim gasket (5 – Fig. S3-8) thickness between bottom of cylinder and crankcase mounting surface. With piston at top dead center, top of piston must be even with to 0.2 mm (0.008 inch) below top edge of cylinder.

OIL PUMP

The engine oil pump (3 – Fig. S3-9) is mounted on the front of the crankcase and is driven by the crankshaft gear. The oil pressure relief valve assembly is located in drilled passage in the side of crankcase behind the fuel filter.

To gain access to pump, crankshaft front pulley and timing gear cover must first be removed. Unbolt and remove pump drive gear, then remove pump housing assembly.

Inspect pump gears and housing for excessive wear or damage and renew if necessary. To reinstall pump, reverse the removal procedure.

TIMING GEARS AND FRONT COVER

To gain access to timing gears, first remove crankshaft front pulley and cooling fan housing. Unbolt and remove crankcase front cover. Rotate crankshaft until number 1 piston is at TDC on compression stroke and timing marks (M – Fig. S3-10) on gears are aligned as shown. Then, remove gears (Fig. S3-9) as needed.

To reassemble, first install idler gear (3 – Fig. S3-10) aligning center timing marks with mark on crankshaft gear (1). Turn valve camshaft and injection pump camshaft so flange holes (F) and locating pin hole (P) are positioned as shown. Install gears (2 and 4) aligning their timing marks with the respective marks on idler gear and insert locating pin into hole in camshaft gear and shaft flange. Secure gears with socket head retaining screws. Check injection pump timing as outlined in MAINTENANCE section.

VALVE CAMSHAFT AND CAM FOLLOWERS

The camshaft rides in a bored sleeve bearing at front of crankcase and in unbushed bores at center and rear of crankcase. The camshaft must be removed before the mushroom type cam followers can be removed.

To remove camshaft, first remove timing gear cover and camshaft drive gear (6 – Fig. S3-9) as outlined in TIMING GEAR section. Remove cylinder heads, push rods and push rod tubes. Remove fuel transfer pump and push rod. Raise cam followers off cam lobes and support with suitable tools. Remove camshaft retaining plate (7), then carefully withdraw camshaft. Cam followers (4) may now be removed through bottom of crankcase after removing oil pan. Be sure to identify cam followers as they

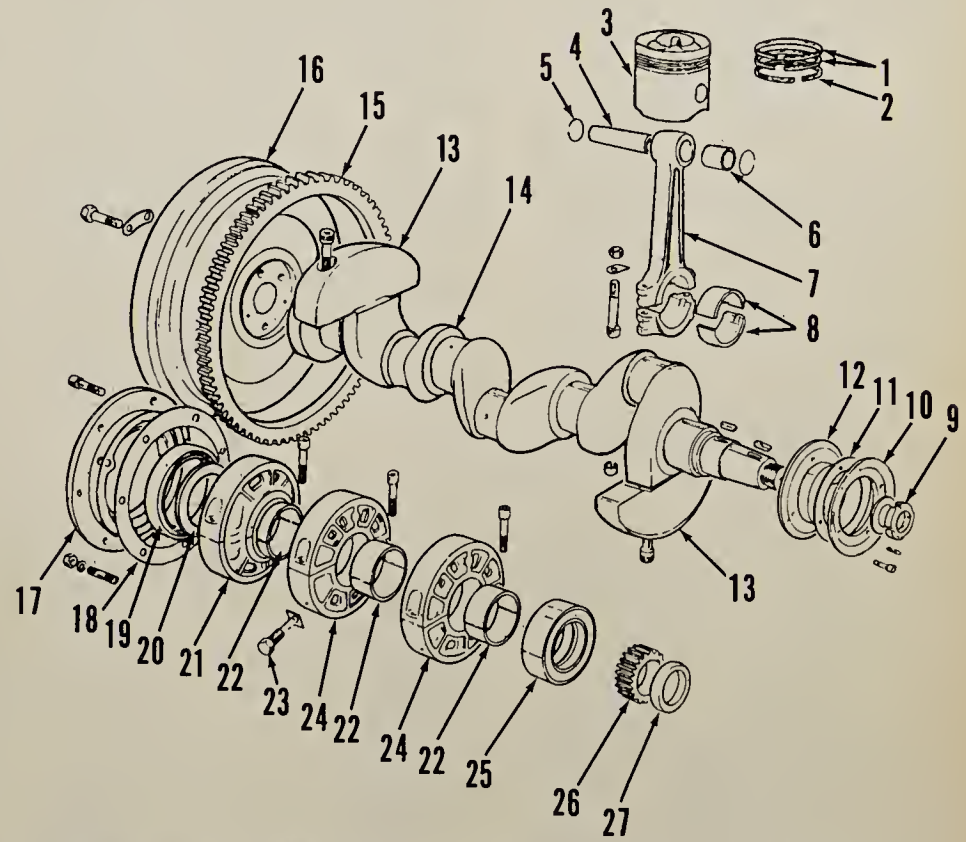


Fig. S3-11 – Exploded view of piston, connecting rod end crenksheft assembly.

1. Compression rings
2. Oil control ring
3. Piston
4. Piston pin
5. Retaining rings
6. Bushing
7. Connecting rod
8. Rod bearing
9. Nut
10. Pulley half
11. Shim
12. Pulley half
13. Counterweight
14. Crankshaft
15. Ring gear
16. Flywheel
17. Seal retainer
18. Gasket
19. Oil seal
20. Thrust washer
21. Rear bearing carrier
22. Main hearings
23. Locating screw
24. Center hearing carrier
25. Front main bearing
26. Crankshaft gear
27. Oil seal

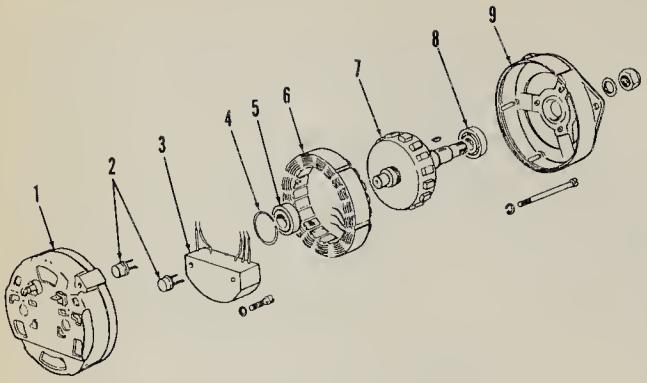


Fig. S3-12—Exploded view of alternator assembly.
1. Stator housing
2. Diodes
3. Voltage regulator
4. Retaining ring
5. Bearing
6. Stator
7. Rotor
8. Bearing
9. End cover

are removed so they can be reinstalled in their original locations.

Inspect cam lobes and bearing journals for scoring, wear and other damage. Diameter of bearing journals (from front to rear) is 41.950-41.975 mm (1.6516-1.6526 inches) for first journal, 40.950-41.975 mm (1.6122-1.6132 inches) for second journal, 39.950-39.975 mm (1.5728-1.5738 inches) for third journal and 29.959-29.980 mm (1.1795-1.1803 inches) for rear journal. Inner diameter of camshaft support bores in the crankcase (from front to rear) is 42.020-42.045 mm (1.6543-1.6553 inches) for front bored sleeve bearing, 41.020-41.045 mm (1.6150-1.6160 inches) for second bore, 40.020-40.045 mm (1.5756-1.5766 inches) for third bore and 30.020-30.040 mm (1.1819-1.1827 inches) for rear bore. Desired camshaft running clearance in crankcase is 0.040-0.081 mm (0.0016-0.0032 inch) for rear journal and 0.045-0.095 mm (0.0018-0.0037 inch) for all other journals. Camshaft end play is set by retaining plate (7). Desired end play is 0.040-0.165 mm (0.0016-0.0065 inch).

Thoroughly lubricate cam followers, camshaft bearing journals and lobes during installation. Reinstall by reversing the removal procedure. Refer to TIMING GEARS section for proper installation and timing of camshaft gear.

INJECTION PUMP CAMSHAFT

To remove injection pump camshaft (18—Fig. S3-9), first remove injection pump, timing gear cover and camshaft drive gear (17). Remove retaining plate (7), then withdraw camshaft.

Inspect camshaft bearing journals and cam lobes for scoring, wear or other damage. If cam lobes are worn or damaged, inspect injection pump tappet rollers also. Camshaft front journal diameter should be 49.950-49.975 mm (1.9665-1.9675 inches) and rear journal diameter should be 29.959-29.980 mm (1.1795-1.1803 inches). Crankcase bearing bore inner diameter should be 50.000-50.025 mm (1.9685-1.9695 inches) for front sleeve bearing and 30.000-30.021 mm (1.1811-1.1819 inches) for rear bore. Desired operating clearance in crankcase is 0.025-0.075 mm (0.001-0.003 inch) for front journal and 0.020-0.062 mm (0.0008-0.0024 inch) for rear journal. Camshaft end play is controlled by retaining plate (7). Desired end play is 0.040-0.165 mm (0.0016-0.0065 inch).

Reinstall camshaft by reversing the removal procedure. Install and time the drive gear as outlined in TIMING GEARS section. Check injection pump timing as outlined in MAINTENANCE section.

CRANKSHAFT AND BEARINGS

The crankshaft rides in four main bearings. The front bearing (25—Fig. S3-11) is a one-piece assembly while the two center bearings and the rear bearing are split bearing inserts (22) contained in two-piece bearing supports (21 and 24).

To remove the crankshaft, first remove oil pan, front pulley and timing gear cover. Remove flywheel and rear seal retainer (17). Remove connecting rod caps and push rods and pistons into cylinders for clearance. Remove center bearing support locating screws (23), then carefully withdraw crankshaft out rear of crankcase.

Standard diameter of main journals is 59.960-59.980 mm (2.3606-2.3614 inches). Main bearing inner diameter should be 60.011-60.054 mm (2.3626-2.3643 inches). Desired main bearing clearance is 0.031-0.094 mm (0.0012-0.0037 inch). Undersize main bearings are available.

Crankpin standard diameter is 53.022-53.035 mm (2.0875-2.0880 inches). Desired rod bearing clearance is 0.038-0.086 mm (0.0015-0.0034 inch). Undersize bearings are available.

Crankshaft end play should be 0.070-0.259 mm (0.003-0.010 inch). End play is adjusted by changing thrust washer (20) thickness.

When reinstalling crankshaft, be sure to align timing gear timing marks as shown in Fig. S3-10. Renew oil seals (19 and 27), if necessary, and lubricate lip of seals with grease prior to reassembly. Tighten bearing support socket head screws to 45-49 N·m (33-36 ft.-lbs.). Tighten counterweight (13) cap screws, if removed, to 58-64 N·m (43-47 ft.-lbs.). Tighten flywheel cap screws to 64-65 N·m (47-48 ft.-lbs.). Complete installation. by reversing the removal procedure.

ELECTRICAL SYSTEM

The electrical system is 12-volt negative ground. The alternator is mounted in front of the engine cooling fan and is belt driven by the crankshaft. Alternator and blower fan belt tension is adjusted by adding or removing shims (11—Fig. S3-11) between crankshaft pulley halves on early production engines or by moving an idler pulley on late production engines. An integral solid-state regulator controls alternator output. See Fig. S3-12 for an exploded view of alternator.

A BOSCH or HARELLI starter motor is used on all engines. Refer to Fig. S3-13 for an exploded view of starter assembly.

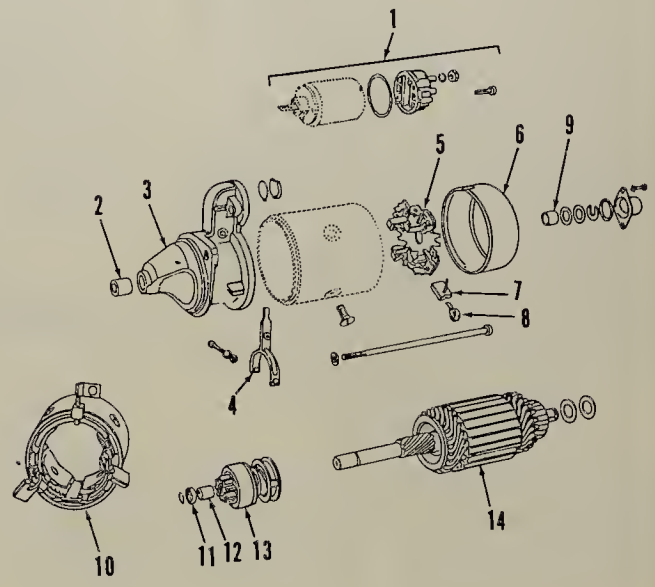


Fig. S3-13—Exploded view of electric starter motor.
1. Solenoid
2. Bushing
3. Drive end housing
4. Lever
5. Brush frame
6. Cover
7. Brush
8. Spring
9. Bushing
10. Field coil & housing
11. Retainer
12. Bushing
13. Starter drive
14. Armature

SLANZI

Model	No. Cyls.	Bore	Stroke	Displ.
DVA1800	2	100 mm (3.937 in.)	114 mm (4.488 in.)	1792 cc (109 cu. in.)
DVA2700	3	100 mm (3.937 in.)	114 mm (4.488 in.)	2686 cc (164 cu. in.)
DVA3600	4	100 mm (3.937 in.)	114 mm (4.488 in.)	3585 cc (219 cu. in.)
DVA3600TB	4	100 mm (3.937 in.)	114 mm (4.488 in.)	3585 cc (219 cu. in.)

All engines are four-stroke, air-cooled, direct injection diesels with vertical inline cylinders. Crankshaft rotation is counterclockwise at flywheel end. Number one cylinder is nearest crankshaft pulley end of engine. Firing order for DVA2700 is 1-3-2 and for DVA3600 and DVA3600TB is 1-3-4-2. DVA3600TB engine is equipped with a turbocharger.

MAINTENANCE

LUBRICATION

Recommended engine oil is SAE 20W-20 when ambient temperature is below 0°C (32°F). When temperature will be above 0°C (32°F), use SAE 30 for winter operation or SAE 40 for summer operation. Multigrade oil is acceptable for use in all temperatures. Manufacturer suggests using SAE 15W-40. Regardless of oil viscosity, use only premium grade, heavy-duty, diesel engine oil meeting API CC specifications.

Manufacturer recommends changing the engine oil after every 150 hours of operation. Oil should be drained while engine is hot. The engine oil filter should be changed after every 450 hours of operation. Crankcase capacity is approximately 6.7 liters (7.1 quarts) for DVA1800, 10 liters (10.5 quarts) for DVA2700 and 13.5 liters (14.2 quarts) for DVA3600 and DVA3600TB.

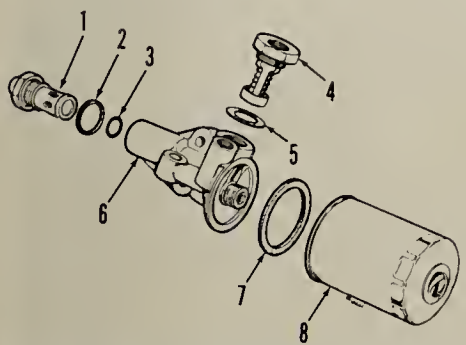


Fig. S4-1—Engine oil pressure relief valve (1) and oil cooler bypass valve (4), if equipped, are located in oil filter adapter housing.

1. Pressure relief valve
2. Gasket
3. "O" ring
4. Oil cooler bypass valve
5. Gasket
6. Filter adapter housing
7. Gasket
8. Oil filter

The engine oil pressure relief valve (1 – Fig. S4-1) and oil cooler bypass valve (4), if so equipped, are located in the oil filter adapter housing (6).

FUEL SYSTEM

FUEL FILTER AND BLEEDING. All engines are equipped with a renewable fuel filter. Manufacturer recommends renewing filter element after every 200 hours of operation or more often if engine indicates signs of fuel starvation (surging or loss of power). After renewing fuel filter, air must be bled from the fuel system.

NOTE: A plastic filter screen is located in fuel transfer pump inlet. If engine fails to run properly after main fuel filter element has been renewed, remove and clean pump filter screen (3 – Fig. S4-3).

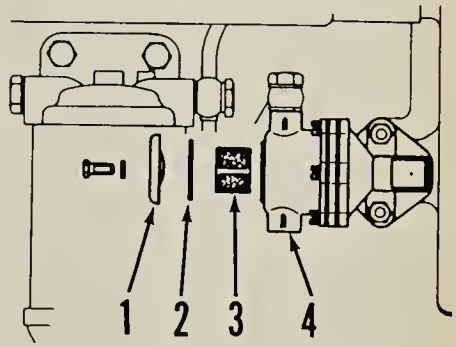


Fig. S4-3—A plastic filter screen (3) is located on inlet side of fuel transfer pump (4).

1. Cover
2. Gasket
3. Filter screen
4. Fuel transfer pump

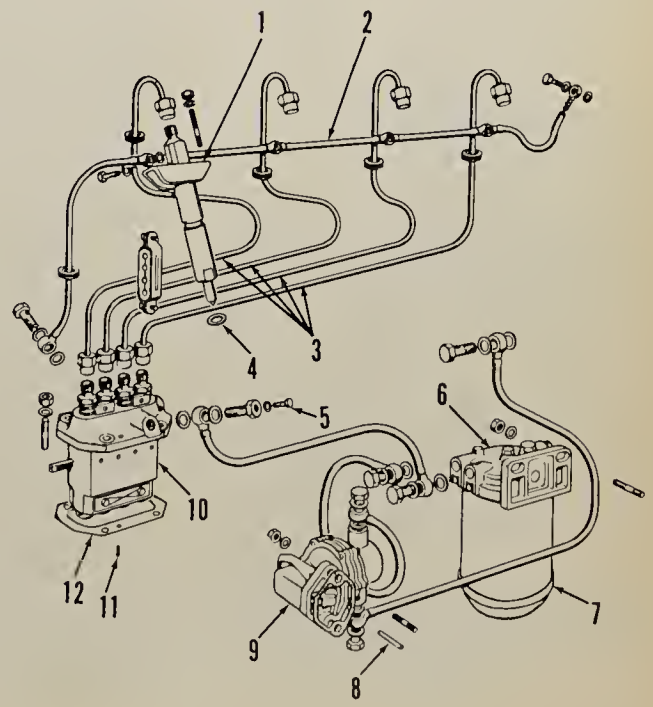


Fig. S4-2—Typical fuel system components used on DVA3600 engine. Other engines are similar.

1. Injector
2. Fuel return line
3. High pressure injector lines
4. Nozzle gasket
5. Bleed screw
6. Bleed screw
7. Fuel filter
8. Push rod
9. Fuel transfer pump
10. Injection pump
11. Pin
12. Shim gasket

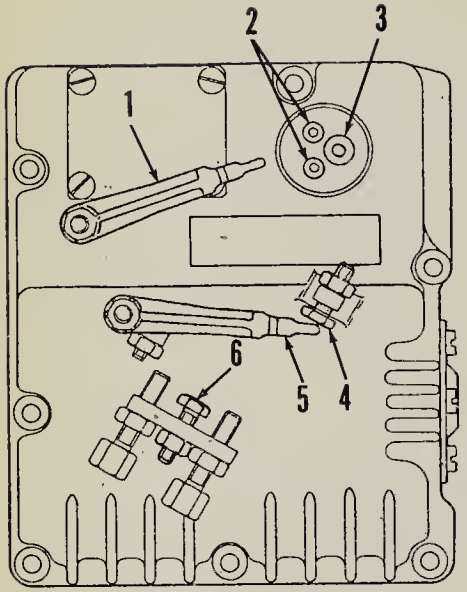


Fig. S4-4—Engine speed adjusting screws are located on governor cover.

1. Stop lever
2. Fuel limiting device screws
3. Extra fuel knob
4. Low speed screw
5. Throttle lever
6. High speed screw

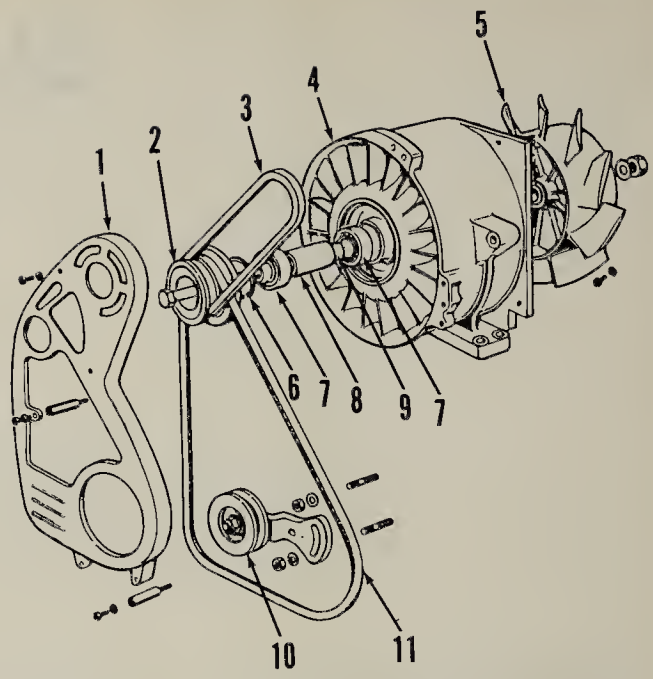


Fig. S4-6—Exploded view of axial flow engine cooling fan.

1. Belt guard
2. Pulley
3. Alternator belt
4. Stator housing
5. Fan
6. Snap ring
7. Bearings
8. Spacer
9. Fan shaft
10. Idler & belt tightener
11. Drive belt

To bleed air from fuel system, loosen bleed screw (6–Fig. S4-2) on filter mounting bracket. Manually operate transfer pump until air-free fuel flows from bleeder, then retighten screw. Loosen bleed screw (5) on injection pump fuel inlet. Actuate transfer pump until fuel flows from bleeder, then retighten the screw. Continue to operate transfer pump until resistance is felt indicating fuel system is pressurized.

If engine fails to start at this point, loosen high pressure fuel lines (3) at injectors. Set throttle control in full speed position. Crank engine until fuel is discharged at loosened fuel line connections, then retighten fittings and start engine.

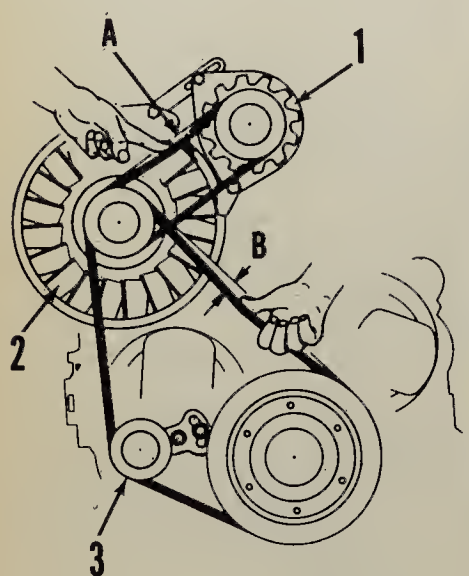


Fig. S4-5—Drive belt tension (A and B) should be checked after every 150 hours of operation. Refer to text for adjustment.

1. Alternator
2. Cooling fan
3. Idler

ENGINE SPEED ADJUSTMENT

Engine should be at normal operating temperature when checking and adjusting engine speed settings. Low and high idle (no-load) speeds are adjusted using throttle lever stop screws (4 and 6–Fig. S4-4) on outside of governor housing. Turning screw (4) clockwise will decrease low idle speed and turning screw (6) clockwise will increase maximum governed speed. Adjust screws as required to obtain governed speeds as specified for engine application.

Injection pump maximum fuel delivery is adjusted by loosening the two screws (2) and rotating fuel limiting device. Pulling knob (3) of fuel limiting device outward will allow pump control rack to move to maximum fuel delivery position to provide extra fuel delivery for starting.

INJECTION PUMP TIMING

The injection pump is actuated by the injection pump camshaft (2–Fig. S4-15). Injection timing is adjusted by loosening timing gear (1) retaining screws and rotating camshaft within limits of retaining screw slots in timing gear.

To check injection timing, first rotate crankshaft pulley clockwise until number 1 piston is on compression and second mark (top dead center) on pulley is aligned with timing pointer on front cover. Disconnect injector line for number 1 cylinder from injection pump. Connect a fuel flow sight gage (special tool number 59.40.50) to number one discharge fitting on pump. If tool is not available, remove delivery valve holder (1–Fig. S4-9), spring (3) and delivery valve (5), then reinstall delivery valve holder. Remove governor cover and position pump control rack at half speed setting. Maintain this setting during timing check. Connect fuel supply to pump. Note that fuel should flow from delivery valve holder at this time if delivery valve is removed. Rotate crankshaft pulley counterclockwise about ½ turn, then slowly turn clockwise (normal direction of rotation) until first drop of fuel is observed at sight gage tool, or until fuel flow just stops if delivery valve is removed. At this point, beginning of injection occurs and first mark on crankshaft pulley should be aligned with timing pointer. If timing mark is not aligned, remove camshaft gear inspection cover from crankcase front cover. Loosen camshaft gear mounting screws, then rotate injection pump camshaft within limits of camshaft gear screw slots to obtain correct timing. Rotating camshaft clockwise will advance timing and counterclockwise will retard timing.

DRIVE BELTS

The cooling fan drive belt and alternator drive belt tension should be checked after every 150 hours of operation. Under thumb pressure, cooling fan belt should deflect 13-15 mm (17/32-19/32 inch) as shown at (B–Fig. S4-5). Belt tension is adjusted by moving the idler pulley (3). The alternator drive belt should deflect 8-10 mm (5/16-⅜ inch) under finger pressure as shown at (A). To adjust, loosen nuts securing alternator (1) and reposition alternator to ob-

tain recommended tension. After adjusting belt tension, check for interference between alternator and belt guard. If alternator contacts the belt guard, renew alternator drive belt.

REPAIRS

TIGHTENING TORQUES

Refer to the following table for special tightening torques. All fasteners are metric.

Connecting rod.....57-61 N·m (42-45 ft.-lbs.)
Crankcase crossbeam.....42-46 N·m (31-34 ft.-lbs.)
Crankshaft counterweight..59-63 N·m (44-47 ft.-lbs.)
Cylinder head.....76-80 N·m (56-59 ft.-lbs.)
Flywheel.....105-111 N·m (78-82 ft.-lbs.)
Injector.....18-20 N·m (13-15 ft.-lbs.)
Main bearing cap.....172-182 N·m (127-134 ft.-lbs.)

COOLING FAN

An axial flow fan, belt driven by the crankshaft, provides engine cooling air flow. To disassemble fan, first remove belt guard (1 – Fig. S4-6) and drive belts (3 and 11). Remove fan retaining nut and withdraw fan (5). Remove snap ring (6), then tap fan shaft (9) and bearings (7) out of stator housing (4).

Inspect all parts and renew if necessary. To reinstall, reverse the removal procedure. Refer to DRIVE BELTS section to adjust belt tension.

VALVE ADJUSTMENT

To adjust valve clearance, first remove valve covers and rotate crankshaft until number 1 piston is at TDC on compression stroke (both rocker arms should be free to move). With engine cold (room temperature), valve clearance should be 0.15 mm (0.006 inch) for intake and exhaust. Turn rocker arm adjusting screw (6 – Fig. S4-7) until appropriate size feeler gage can be inserted between rocker arm and valve stem end. Recheck adjustment after retightening screw locknut.

Rotate crankshaft to position next piston in firing order at TDC on compression stroke and adjust valves for that cylinder.

CYLINDER HEAD AND VALVE SYSTEM

To remove cylinder heads, first remove intake and exhaust manifolds

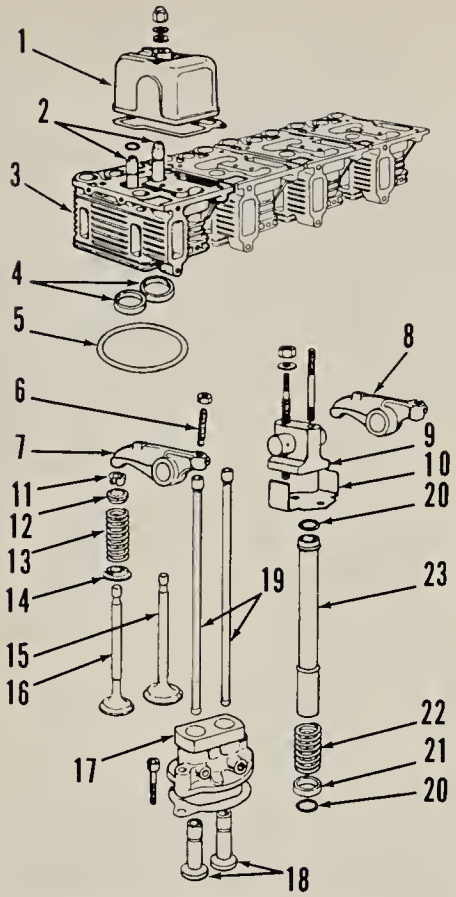


Fig. S4-7—Exploded view of cylinder heads and valve system.

1. Valve cover
2. Valve guides
3. Cylinder heads
4. Valve seat inserts
5. Head gasket
6. Adjusting screw
7. Rocker arm (exhaust)
8. Rocker arm (intake)
9. Rocker arm shaft
10. Rocker arm retainer
11. Valve keepers
12. Retainer
13. Valve spring
14. Spring seat
15. Intake valve
16. Exhaust valve
17. Cam follower guide
18. Cam followers
19. Push rods
20. Gasket
21. Retainer
22. Spring
23. Push rod tube

and cooling air shroud. Disconnect and remove fuel lines from injectors and immediately plug all openings. Remove the injectors. Remove cylinder head stud nuts and lift off cylinder heads. Remove valve cover and rocker arm support for access to valves.

Valve stem diameter is 8.961-8.970 mm (0.3528-0.3531 inch) for intake and exhaust. Valve guide inner diameter should be 9.005-9.020 mm (0.3545-0.3551 inch). Desired clearance of valve stem in guide is 0.035-0.059 mm (0.0014-0.0023 inch). Valve guides are renewable. When installing new guides, use a suitable installing tool to avoid damaging guides. After installation, check fit of valve stem in guide. Replacement guides are presized and should not require reaming if carefully installed.

Renewable valve seat inserts are used for intake and exhaust. Inserts should have an interference fit of 0.115-0.160 mm (0.0045-0.0063 inch) in cylinder head counterbore. Chilling inserts in dry ice prior to installation will ease assembly. When properly installed, valve seat should be recessed 1.03-1.18 mm (0.040-0.046 inch) below cylinder head surface. Position valves in cylinder head and measure distance top of valve is recessed below cylinder head surface. Valve recession should be 0.9-1.1 mm (0.035-0.043 inch). If valve recession is excessive, renew valve seat. If recession is less than specified, regrind valve seat.

Rocker arm pivot pin diameter is 20.035-20.043 mm (0.7888-0.7891 inch). Rocker arm bearing inner diameter should be 20.030-20.060 mm (0.7886-0.7897 inch). Desired rocker arm operating clearance is 0.012-0.045 mm (0.0005-0.0018 inch).

The injector nozzle tip should extend 2.3-2.7 mm (0.090-0.106 inch) beyond cylinder head surface. Adjust nozzle position using shim gaskets between nozzle valve and bottom of cylinder head nozzle bore.

If pistons or cylinders were renewed, refer to CYLINDERS section and check and adjust piston height in cylinder before reinstalling cylinder heads. To reinstall heads, reverse the removal procedure. Be sure to renew push rod tube seals if necessary. Tighten cylinder head stud nuts evenly to 76-80 N·m (56-59 ft.-lbs.). Adjust valve clearance as previously outlined.

INJECTOR

REMOVE AND REINSTALL. Before removing injectors, thoroughly clean injector, fuel lines and surrounding area. Disconnect fuel return line and high pressure line at injector and plug all openings. Unscrew retaining nuts and withdraw injector from cylinder head.

Before reinstalling injector, make certain nozzle bore in cylinder head is clean. Reinstall injector and tighten stud nuts to 18-20 N·m (13-15 ft.-lbs.).

TESTING. A suitable test stand is required to check injector operation. Only clean, approved testing oil should be used to test injector.

WARNING: Fuel leaves the injector nozzle with sufficient force to penetrate the skin. When testing, keep yourself clear of nozzle spray.

Connect injector to tester and operate tester lever a few quick strokes to purge air from injector and to make sure nozzle valve is not stuck. When operating properly, injector nozzle will emit a buzzing sound and produce a uniform spray pattern.

To check opening pressure, slowly operate tester lever while observing the pressure gage reading. Opening pressure should be 20000-21000 kPa

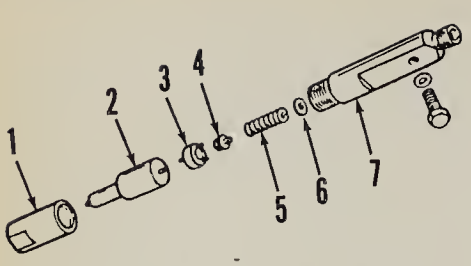


Fig. S4-8—Exploded view of injector assembly.

1. Nozzle holder nut
2. Nozzle valve
3. Spacer
4. Spring seat
5. Spring
6. Shim
7. Injector body

(2900-3045 psi). Opening pressure is adjusted by varying the thickness of shim (6–Fig. S4-8).

Operate tester lever slowly to maintain pressure at 2000 kPa (300 psi) below opening pressure and check for leakage past nozzle valve seat. If a drop forms at nozzle tip within a 10 second period, nozzle valve is not seating and injector must be overhauled or renewed.

OVERHAUL. To disassemble injector, secure nozzle body (7–Fig. S4-8) in a vise or holding fixture. Remove nozzle holder nut (1) and withdraw nozzle valve (2), spacer (3), spring seat (4), spring (5) and shim (6). If disassembling more than one injector, be sure to keep parts for each injector separated as they should not be interchanged.

Thoroughly clean all parts in a suitable solvent. Do not use steel wire brush or sharp metal tools to clean injector components. Make certain the nozzle valve needle slides freely in nozzle valve body. If needle sticks, reclean or renew nozzle valve assembly. Nozzle valve spray holes are 0.27 mm (0.010 inch) in diameter. Spray holes may be cleaned by inserting a cleaning wire that is slightly smaller in diameter than the spray hole.

When reassembling injector, be sure all parts are clean and wet with diesel fuel. Recheck injector operation as outlined in TESTING section.

INJECTION PUMP

To remove injection pump, first remove cooling air shroud. Disconnect and remove fuel lines and immediately plug all openings to prevent entry of dirt. Remove retaining nuts and lift out injection pump.

An exploded view of injection pump is shown in Fig. S4-9. It is recommended that injection pump be tested and serviced only by a shop qualified in diesel fuel injection repair.

When reinstalling pump, note that pump mounting gasket thickness will affect pump timing. To determine correct gasket thickness, rotate crankshaft until one lobe of injection pump camshaft is pointing downward. Measure distance from mounting surface of crankcase to base of camshaft lobe. Assemble gasket thickness necessary to obtain mounting dimension of 82.6-83.0 mm (3.252-3.268 inches). Check injection pump timing as outlined in MAINTENANCE SECTION.

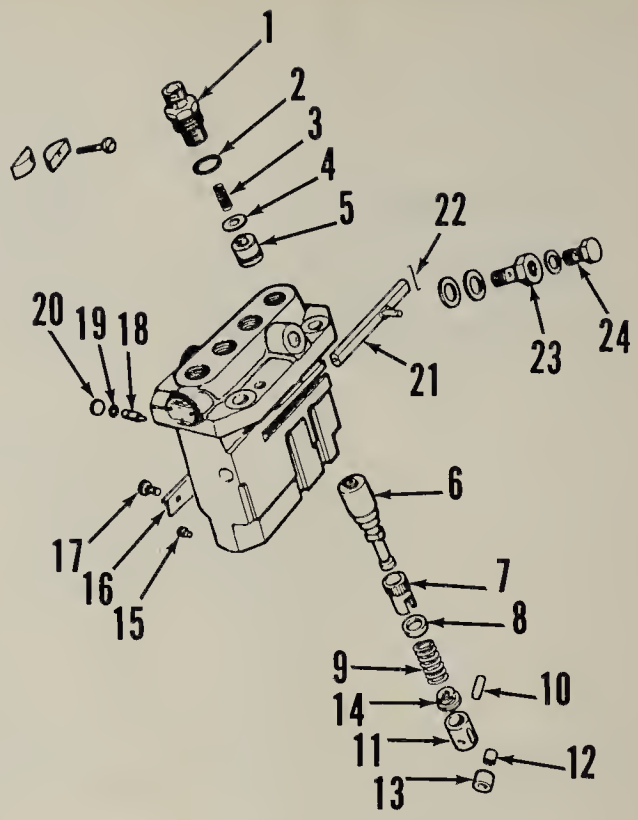


Fig. S4-9—Exploded view of injection pump assembly.

1. Delivery valve holder
2. Gasket
3. Spring
4. Gasket
5. Delivery valve
6. Pumping element
7. Sleeve
8. Retainer
9. Spring
10. Pin
11. Tappet
12. Inner roller
13. Outer roler
14. Retainer
15. Screw
16. Retainer plate
17. Screw
18. Eccentric
19. Gasket
20. Plug
21. Control rack
22. Retainer
23. Fuel inlet banjo bolt
24. Bleed screw

PISTON AND ROD UNIT

The pistons and connecting rods may be removed after removing cylinder heads and oil pan. Number pistons and rods as they are removed so they can be reinstalled in their original locations.

To reinstall piston and rod, reverse the removal procedure. Make certain locating tabs of connecting rod bearing inserts engage notches in rod and cap and are located on the same side. Tighten rod cap nuts to 57-61 N·m (42-45 ft.-lbs.).

If connecting rod or piston was renewed, refer to CYLINDER section and measure piston height in cylinder.

PISTON, PIN AND RINGS

The piston is equipped with two compression rings and an oil control ring. Recommended piston ring end gap is 0.40-0.60 mm (0.016-0.023 inch) for top compression ring, 0.35-0.55 mm (0.014-0.021 inch) for second compression ring and 0.25-0.45 mm (0.010-0.018 inch) for oil control ring. Standard piston skirt diameter, measured at bottom of skirt perpendicular to piston pin, is 99.878-99.893 mm (3.9322-3.9328 inches).

Piston pin is retained in piston by two snap rings. Pin diameter is 31.994-32.000 mm (1.2596-1.25987 inches) and piston bore is 31.991-31.997 mm (1.2595-1.2597 inches). Pin is a transition fit in piston bore. Initial fit when cold is 0.009 mm (0.0003 inch) interference to 0.003 mm (0.0001 inch) loose. Heating piston will ease removal and installation of pin.

CONNECTING ROD

The connecting rod small end is fitted with a renewable bushing. The bushing inside diameter should be 32.010-32.020 mm (1.2602-1.2606 inches). Desired clearance between piston pin and bushing is 0.010-0.026 mm (0.0004-0.001 inch).

A precision, insert type bearing is used in big end of connecting rod. With bearing installed and rod cap nuts torqued to 57-61 N·m (42-45 ft.-lbs.), bearing inside diameter should be 59.993-60.018 mm (2.3619-2.3629 inches). Recommended rod bearing clearance is 0.050-0.088 mm (0.002-0.0035 inch). Bearings are available in standard size and undersizes.

CYLINDER

Removable cast iron cylinders are used on all engines. Standard cylinder bore is 100.000-100.020 mm (3.9370-3.9378 inches). Recommended clearance between piston skirt and cylinder is 0.107-0.142 mm (0.004-0.0055 inch). Cylinders that are damaged or excessively worn may be rebored and fit-

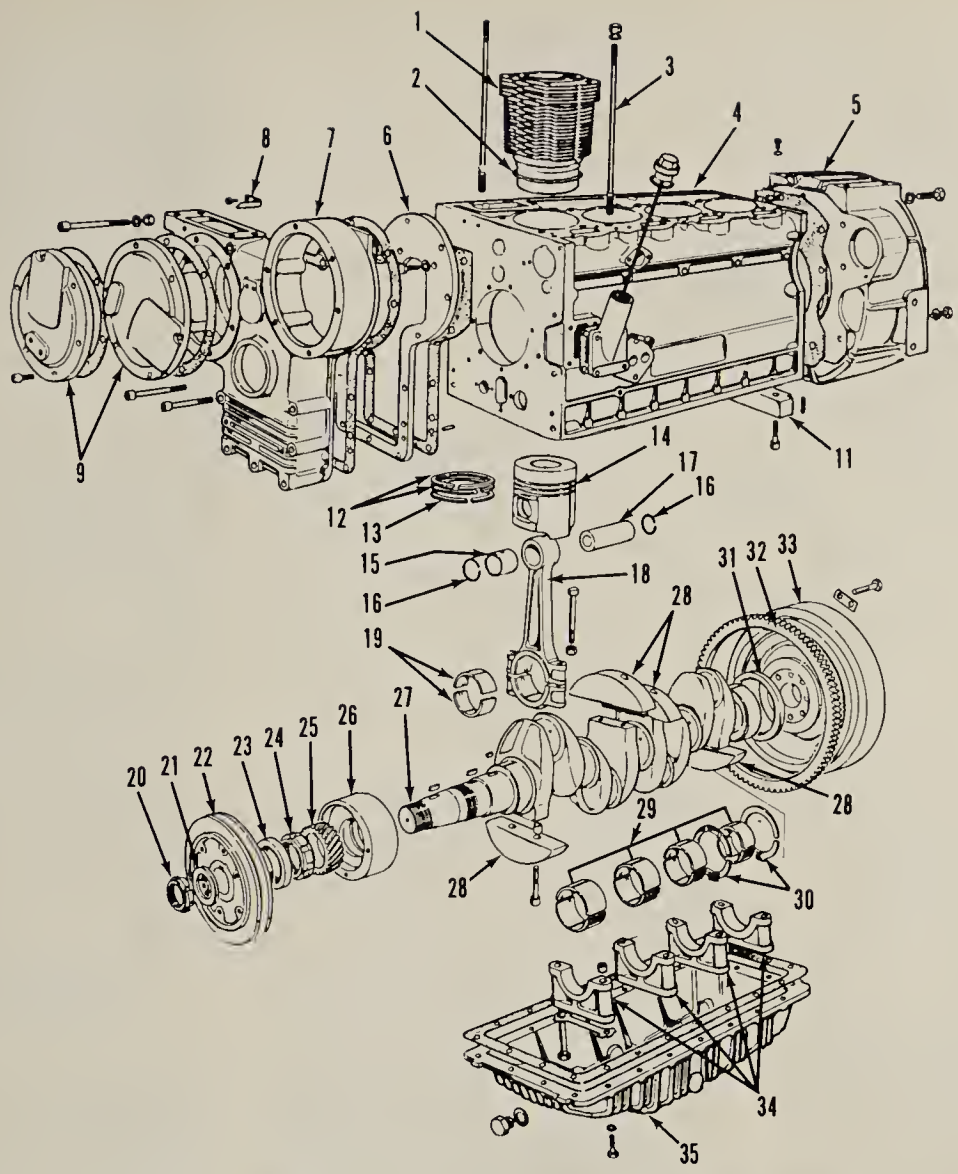


Fig. S4-10—Exploded view of crankcase and crankshaft assembly for DVA3600. Other engines are similar except for number of cylinders.

1. Cylinder
2. Shim gasket
3. Cylinder stud
4. Crankcase
5. Flywheel housing
6. Plate
7. Front cover
8. Timing pointer
9. Timing gear covers
11. Crossbeam
12. Compression rings
13. Oil control ring
14. Piston
15. Bushing
16. Retaining rings
17. Piston pin
18. Connecting rod
19. Rod bearing
20. Nut
21. Washer
22. Pulley
23. Oil seal
24. Nut
25. Gear
26. Front main bearing
27. Crankshaft
28. Counterweights
29. Main bearing inserts
30. Thrust washers
31. Oil seal
32. Ring gear
33. Flywheel
34. Main bearing caps
35. Oil pan

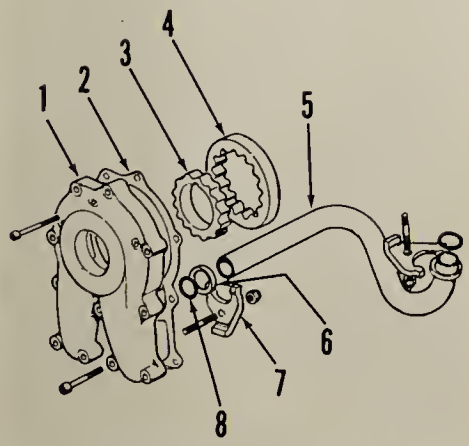


Fig. S4-11—Exploded view of geroter type engine oil pump.

1. Pump housing
2. Gasket
3. Inner rotor
4. Outer rotor
5. Pickup tube
6. Washer
7. Retainer
8. Gasket

ted with 0.5 mm (0.020 inch) oversize piston and rings.

Piston height in cylinder is adjusted by varying thickness of shim gasket (2–Fig. S4-10) between bottom of cylinder and crankcase mounting surface. With piston at top dead center, top of piston must be 0.0-0.2 mm (0.0-0.008 inch) below top edge of cylinder.

OIL PUMP

The gerotor type oil pump is mounted to front of crankcase and is enclosed by the crankcase front cover. The crankshaft extends through the oil pump and drives the pump inner rotor (3–Fig. S4-11).

To gain access to the oil pump, the crankcase front cover must first be removed as outlined in TIMING GEARS AND FRONT COVER section. Remove crankshaft gear, then unbolt and remove oil pump assembly.

Inspect pump components for scoring, excessive wear or other damage. Outer diameter of outer rotor (4) should be 101.511-101.549 mm (3.9965-3.9980 inches) and inner diameter of pump housing (1) should be 101.752-101.852 mm (4.0060-4.0099 inches). Desired clearance between outer rotor and pump housing is 0.203-0.341 mm (0.008-0.013 inch). Pump rotor end clearance

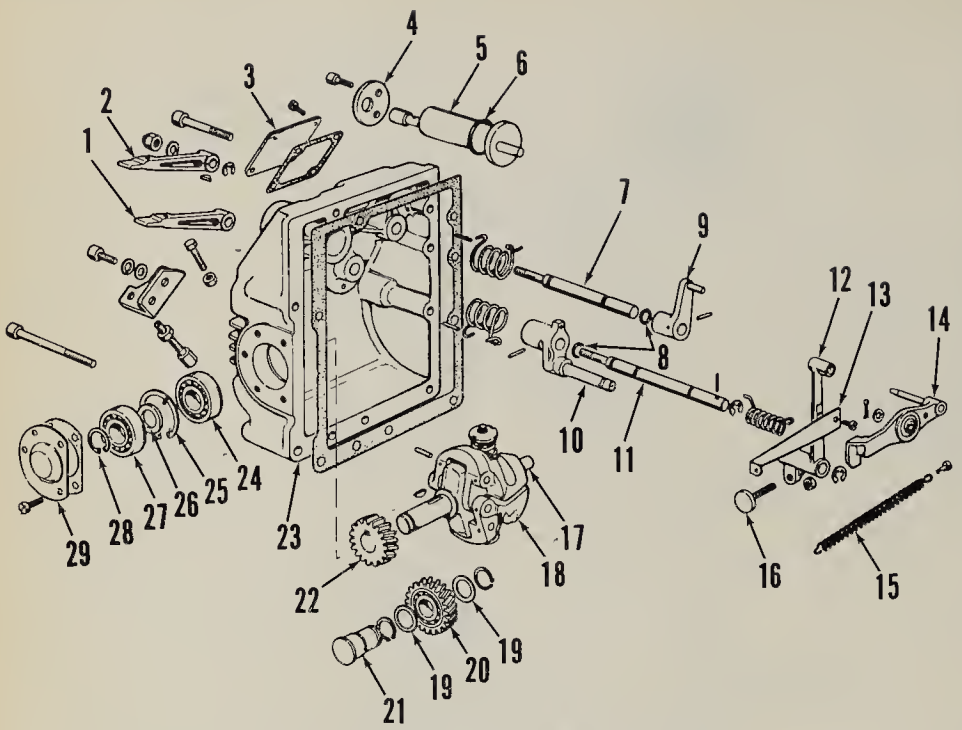


Fig. S4-12—Exploded view of governor assembly.

1. Throttle lever
2. Stop lever
3. Cover
4. Retainer plate
5. Fuel limiting device
6. "O" ring
7. Shaft
8. "O" rings
9. Arm
10. Throttle arm
11. Shaft
12. Governor arm
13. Lever
14. Counter lever
15. Governor spring
16. Adjusting screw
17. Push rod
18. Flyweight assy.
19. Thrust washers
20. Idler gear
21. Shaft
22. Drive gear
23. Governor housing
24. Inner bearing
25. Snap ring
26. Spacer
27. Outer bearing
28. Snap ring
29. Cover

should be 0.008-0.084 mm (0.0003-0.0033 inch) for DVA1800 and DVA2700 or 0.010-0.087 mm (0.0004-0.0034 inch) for DVA3600 and DVA3600TB.

GOVERNOR

All engines are equipped with a flyweight type governor. The governor housing is mounted on the side of crankcase and is driven by a gear on the injection pump camshaft through an idler gear (20–Fig. S4-12).

To remove governor assembly, first remove cover (3) and disconnect governor spring (15) from governor lever (12). Remove housing mounting cap screws and withdraw governor assembly.

To disassemble, remove nuts securing stop lever (2) and throttle lever (1) and remove levers. Remove retaining rings, then withdraw inner stop lever (9) and shaft (7) and throttle lever (10) and shaft (11). Remove retaining plate (4) and withdraw fuel limiting device (5). To remove flyweight assembly (18), remove bearing cover (29) and snap ring (28). Install special removal tool 59.60.22 (available from manufacturer) or similar tool to governor housing as shown in Fig. S4-13. Turn the screw (1) clockwise to push the flyweight shaft out of the outer bearing and remove flyweight assembly. Remove inner bearing and gear (22–Fig. S4-12) from flyweight shaft. Flyweight assembly must be renewed as a complete unit.

To reassemble, proceed as follows: Install snap ring (25) and outer bearing (27) in housing bore. Assemble gear, inner bearing and spacer (26) onto flyweight shaft. Remove push rod (17) from flyweight assembly, then position assembly in housing. Using special installing tool 59.69.16 (2–Fig. S4-14) or similar tool, pull flyweight shaft into outer bearing until outer snap ring (28–Fig. S4-12) can be installed. Insert push rod (17) making certain rounded end faces outward. Complete reassembly of governor by reversing the disassembly procedure.

Refer to ENGINE SPEED ADJUSTMENT section and adjust low and high idle speeds if necessary.

TIMING GEARS AND FRONT COVER

To service timing gears, first rotate crankshaft until number 1 piston is on compression stroke and second timing mark (TDC) on crankshaft pulley is aligned with timing pointer on front cover. Remove crankshaft pulley, drive belts and cooling fan assembly. Unbolt and remove crankcase front cover. Then, remove gears as necessary. Refer to Fig. S4-15.

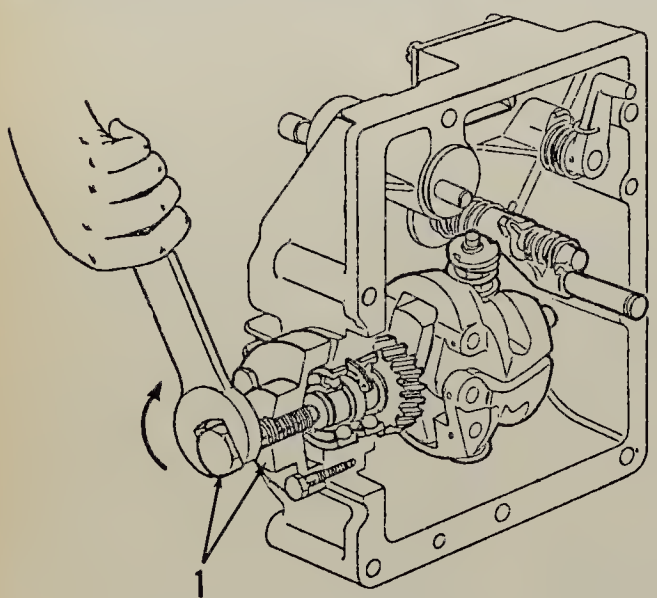


Fig. S4-13—Special tool (1) number 59.60.22 is available from manufacturer to remove governor flyweight.

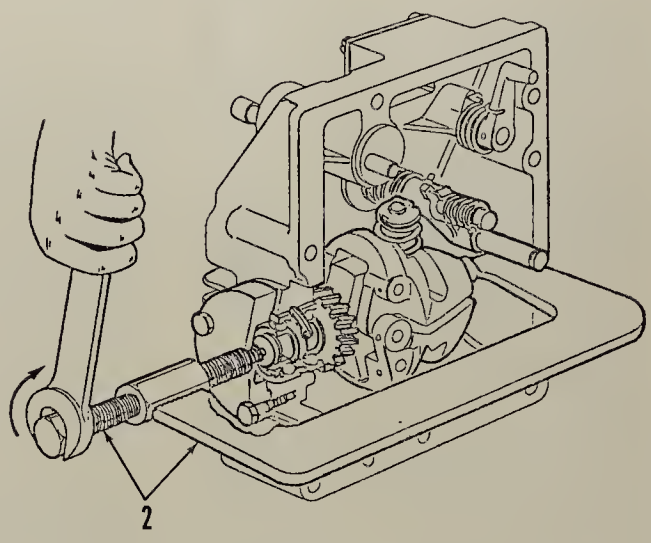


Fig. S4-14—Special tool (2) number 59.69.16 should be used to reinstall flyweight assembly.

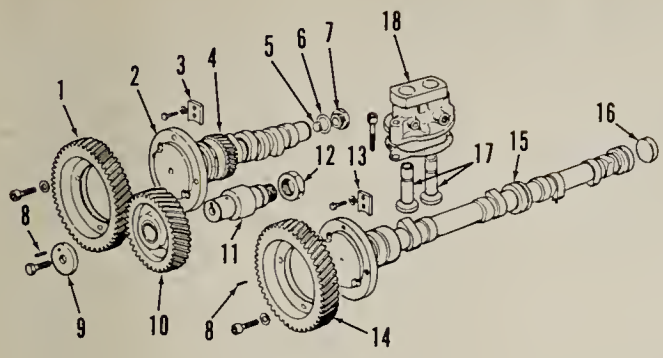


Fig. S4-15—Exploded view of timing gears, valve camshaft and fuel injection camshaft.

1. Gear
2. Injection pump camshaft
3. Retainer
4. Gear
5. Coupling
6. Gasket
7. Plug
8. Locating pin
9. Washer
10. Idler gear
11. Idler shaft
12. Nut
13. Retainer
14. Gear
15. Valve camshaft
16. Plug
17. Cam followers
18. Cam follower guide

To reassemble, reverse the disassembly procedure. Be sure timing marks on the gears are aligned and locating pin (8) is installed in valve camshaft gear (14). Check and adjust injection timing as outlined in INJECTION PUMP TIMING section.

VALVE CAMSHAFT AND CAM FOLLOWERS

The camshaft is supported by a bored sleeve bearing at front of crankcase and by unbushed bores in center and rear of crankcase. Mushroom type cam followers (17—Fig. S4-15) operate in cam follower housings (18).

To remove the camshaft, first remove cylinder head, push rods, push rod tubes and crankcase front cover as previously outlined. Disconnect oil lines from cam follower housings, then unbolt and remove housings with cam followers. Identify components as they are removed so they can be reinstalled in their original locations. Rotate crankshaft until timing marks on gears are aligned, then remove camshaft drive gear (14) and pin (8). Remove camshaft retaining plate (13), then carefully withdraw camshaft.

Inspect camshaft lobes, cam followers, bearing journals and crankcase bearing bores for scoring, wear or other damage. Outside diameter of cam followers should be 14.966-14.984 mm (0.5892-0.5899 inch) and inside diameter of cam follower guide bores should be 15.000-15.018 mm (0.5905-0.5912 inch). Desired operating clearance of cam followers in guide bores is 0.016-0.052 mm (0.0006-0.0020 inch). Camshaft front journal diameter is 47.930-47.955 mm (1.8870-1.8880 inches), center journal diameter is 45.930-45.955 mm (1.8083-1.8093 inches) and rear journal diameter is 44.930-44.955 mm (1.7689-1.7699 inches). Inner diameter of bearing bores in crankcase are 48.000-48.025 mm (1.8898-1.8907 inches) for front sleeve bearing, 46.000-46.025 mm (1.8110-1.8120 inches) for center bore and 45.000-45.025 mm (1.7716-1.7726 inches) for rear bore. Desired clearance between camshaft and crankcase bearing bores is 0.045-0.095 mm (0.0018-0.0037 inch).

To reinstall camshaft, reverse the removal procedure. Camshaft end play should be 0.020-0.098 mm (0.0008-0.0038 inch) and is controlled by camshaft retainer plate (13). Be sure to reinstall cam gear indexing pin (8) and align timing marks on crankshaft gear, idler gear (10) and camshaft gear.

INJECTION PUMP CAMSHAFT

To remove the injection pump camshaft (2—Fig. S4-15), first remove injection pump, fuel transfer pump and crankcase front cover. Rotate crankshaft until timing marks on crankshaft gear, idler gear (10) and camshaft gear (1) are aligned. Remove camshaft gear and camshaft retainer plate (3). Carefully withdraw camshaft from crankcase.

Inspect camshaft journals, cam lobes and injection pump cam followers for scoring, wear or other damage. Camshaft front journal diameter is 57.930-57.950 mm (2.2807-2.2815 inches) and rear journal diameter is 29.940-29.960 mm (1.1787-1.1795 inches). Crankcase front sleeve bearing inner diameter should be 58.000-58.030 mm (2.2835-2.2846 inches) and rear bearing bore should be 30.000-30.025 mm (1.1811-1.1821 inches). Desired operating clearance is 0.050-0.100 mm (0.0020-0.0039 inch) for front journal and 0.040-0.088 mm (0.0016-0.0034 inch) for rear journal.

To reinstall camshaft, reverse the removal procedure. Camshaft end play should be 0.020-0.098 mm (0.0008-0.0038 inch) and is controlled by retainer plate (3). Be sure to align timing gear marks. Check injection pump timing as outlined in MAINTENANCE SECTION.

CRANKSHAFT AND BEARINGS

To remove the crankshaft, first remove crankshaft pulley (22—Fig. S4-10), crankcase front cover (7), flywheel, oil pan, oil pickup tubes and crankcase crossbeam (11). Remove nut (24) and crankshaft gear (25) from front of crankshaft. Remove connecting rod caps and remove rods and pistons or push upward out of the way. Remove main bearing caps, then carefully withdraw crankshaft from crankcase.

Main journal standard diameter is 74.985-75.000 mm (2.9522-2.9527 inches) for front journal and 69.810-69.825 mm (2.7484-2.7490 inches) for all other journals. Front bearing inner diameter should be 75.045-75.085 mm (2.9545-2.9561 inches) and inner diameter of all other bearings (caps installed) should be 69.888-69.926 mm (2.7515-2.7530 inches). Desired main bearing clearance is 0.045-0.100 mm (0.0018-0.0039 inch) for front bearing and 0.063-0.116 mm (0.0025-0.0045 inch) for all other bearings. Standard and undersize bearings are available.

Crankpin standard diameter is 59.930-59.943 mm (2.3595-2.3600 inches) and bearing inner diameter is 59.993-60.018 mm (2.3619-2.3629 inches). Desired rod bearing operating clearance is 0.050-0.088 mm (0.0020-0.0035 inch). Standard and undersize bearings are available.

Crankshaft end play is controlled by

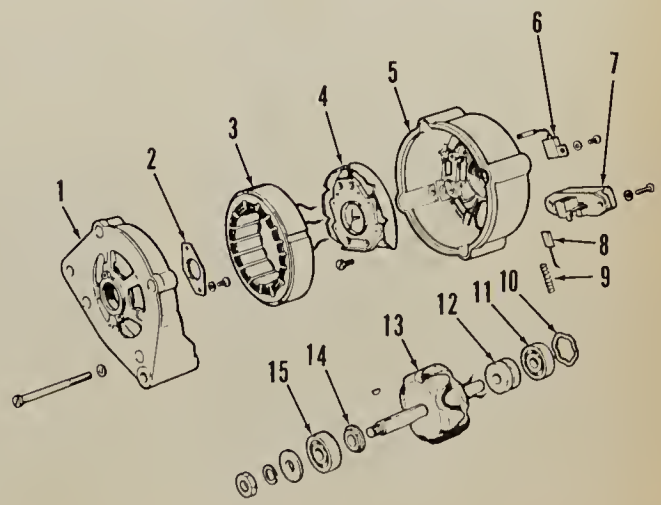


Fig. S4-16—Exploded view of alternator.

1. End frame
2. Bearing retainer
3. Stator
4. Rectifier
5. End cover
6. Condensor
7. Voltage regulator
8. Brush
9. Spring
10. Washer
11. Bearing
12. Commutator ring
13. Rotor
14. Spacer
15. Bearing

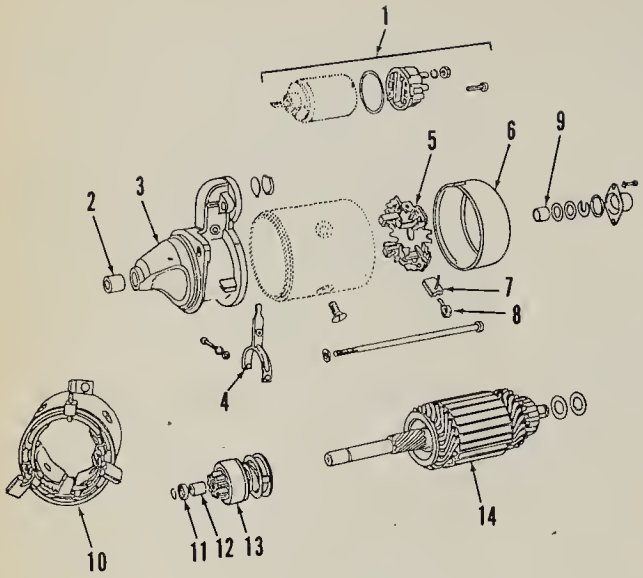


Fig. S4-17—Exploded view of electric starter motor.

1. Solenoid
2. Bushing
3. Drive end housing
4. Lever
5. Brush frame
6. Cover
7. Brush
8. Spring
9. Bushing
10. Field coil & housing
11. Retainer
12. Bushing
13. Starter drive
14. Armature

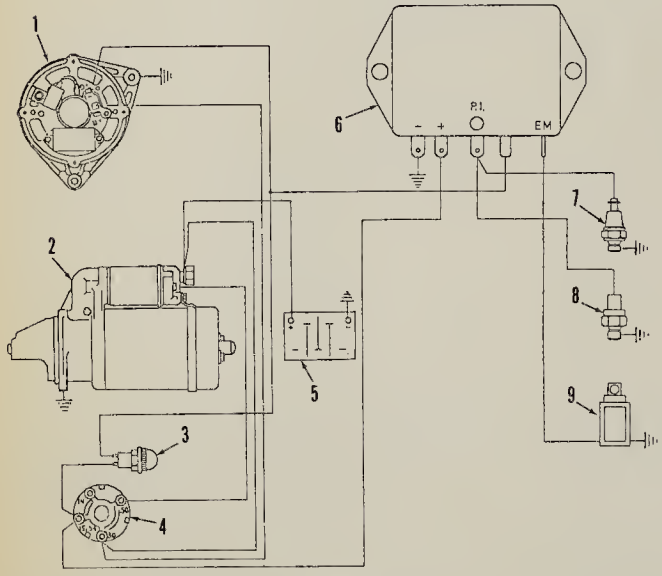


Fig. S4-18—Wiring diagram for engines equipped with safety shut-off system.

1. Alternator
2. Starter
3. Warning light
4. Key switch
5. Battery
6. Safety shut-off module
7. Oil pressure switch
8. Temperature switch
9. Shut-off solenoid

thrust washers (30) mounted on each side of rear main bearing. Washers are available in standard thickness and oversizes of 0.10 mm (0.004 inch) and 0.20 mm (0.008 inch). Desired crankshaft end play is 0.06-0.12 mm (0.0024-0.0047 inch). Be sure to install thrust washers with grooved side facing away from main bearing.

Inspect oil seals (23 and 31) and renew if necessary. Be sure to lubricate oil seal lips with grease prior to reassembly. Reinstall crankshaft by reversing the removal procedure. Tighten main bearing cap bolts to 172-182 N·m (127-134 ft.-lbs.) and crankshaft counterweight (if removed) cap screws to 59-63 N·m (44-47 ft.-lbs.). Tighten crankcase crossbeam (11) screws to 42-46 N·m (31-34 ft.-lbs.) and flywheel cap screws to 105-111 N·m (80-82 ft.-lbs.). Be sure to align timing gear marks when reinstalling crankshaft gear.

ELECTRICAL SYSTEM

The standard electrical system is a 12-volt negative ground system. The externally mounted alternator is controlled by a solid-state, nonadjustable voltage regulator. Refer to Fig. S4-16 for an exploded view of alternator assembly and Fig. S4-17 for an exploded view of starter motor.

Some engines may be equipped with a safety shut-off switch which stops engine if overheating or loss of oil pressure occurs. Refer to Fig. S4-18 for electrical system wiring schematic which shows safety shut-off components.

VOLKSWAGEN

VOLKSWAGEN OF AMERICA INC.
420 Barclay Blvd.
Lincolnshire, Illinois 60069

Model	No. Cyls.	Bore	Stroke	Displ.
068.2	4	76.5 mm (3.012 in.)	80.0 mm (3.150 in.)	1471 cc (90 cu. in.)
068.5	4	76.5 mm (3.012 in.)	86.4 mm (3.400 in.)	1588 cc (97 cu. in.)

These engines are four-stroke, liquid-cooled type with vertical cylinders. The cylinder block is cast iron and the cylinder head is aluminum. The cylinders are numbered 1 through 4 with number 1 cylinder nearest crankshaft pulley. Firing order is 1-3-4-2. Crankshaft rotation is counterclockwise at flywheel end. Engine 068.5 is available with a turbocharger.

MAINTENANCE

LUBRICATION

Recommended oil is API classification CC or CD. Oil weight should be SAE 40 for ambient temperatures above 20°C (70°F), SAE 30 for ambient temperatures between 20°C (70°F) and 0°C (32°F), SAE 20W-20 for ambient temperatures between 0°C (32°F) and minus 10°C (15°F) and SAE 10W for ambient temperatures below minus 10°C (15°F).

Recommended oil change interval is every 150 hours of operation. Crankcase capacity with filter change is 3.5 liters (3.7 quarts) if equipped with a sheet metal oil pan or 4.5 liters (4.7 quarts) if equipped with cast aluminum oil pan.

The engines are equipped with a pressurized lubrication system. Minimum allowable oil pressure is 200 kPa (29 psi) with engine temperature at 80°C (175°F) and running at 2000 rpm. An oil cooler is mounted between oil filter base and oil filter on 068.5 engines equipped with a turbocharger.

NOTE: If an engine failure occurs on a turbocharged engine which contaminates engine oil with metal particles, the oil cooler must be renewed as there is no practical means of cleaning oil cooler internally.

ENGINE SPEED ADJUSTMENT

Low and high idle (no-load) speeds are adjusted using screws (I and H – Fig. V1-1) on injection pump. Low idle speed screw (I) is on engine side of pump. With engine at normal operating temperature, turn adjusting screws as required to obtain specified governed speeds as listed on engine identification plate.

NOTE: Some identification plates may not list a low idle speed. In this case, set idle speed to 920-980 rpm.

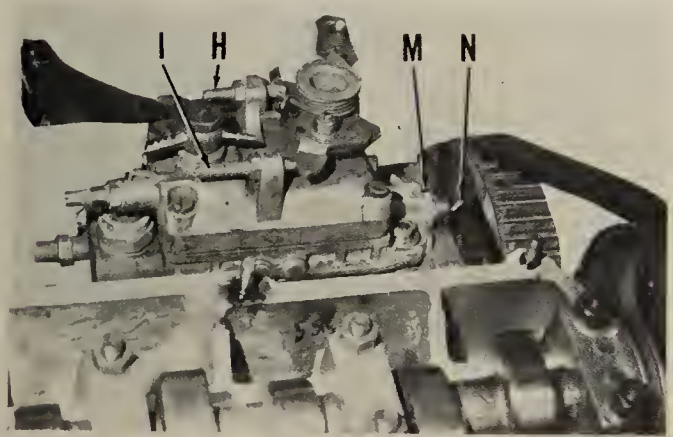


Fig. V1-1—View of fuel injection pump showing location of idle (I) and high (H) speed adjusting screws. Note location of injection pump timing mark (M) and timing notch (N) on mounting plate.

FUEL SYSTEM

FUEL FILTER. The fuel filter is equipped with a drain plug in the bottom of filter canister. Water and sediment trapped in fuel filter should be drained periodically by loosening the drain plug and vent screw (located on filter mounting bracket).

Manufacturer recommends renewing fuel filter after every 300 hours of operation. Fuel filter "O" ring seal should be moistened with diesel fuel prior to reinstalling filter. Bleed air from system as outlined in the following paragraph.

BLEED FUEL SYSTEM. If air enters fuel system, the following procedure may be used to bleed air from fuel system: Loosen fuel outlet fitting or bleed screw at fuel filter and allow fuel to flow until air is expelled, then retighten fitting or bleed screw. Loosen inlet fuel line fitting on injection pump and allow fuel to flow until air is expelled, then retighten fitting.

If engine fails to start at this point, loosen high pressure fuel lines at the injectors. With pump controls in "run" position, crank engine to operate injection pump. Retighten fuel line fittings when fuel is discharged from the lines, then start the engine.

INJECTION PUMP TIMING. Fuel injection timing should be correct if mark (M – Fig. V1-1) on pump flange and notch (N) on mounting plate are aligned when number 1 piston is at TDC on compression stroke. If marks are not aligned or believed inaccurate, refer to

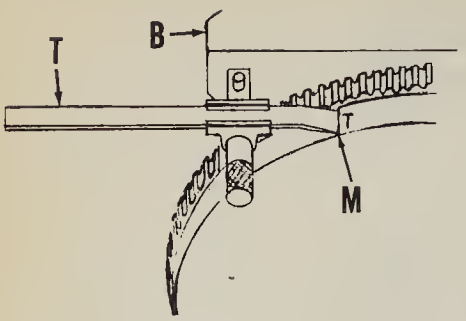


Fig. V1-2—With timing tool 2068 (T) attached to cylinder block (B) as shown, number 1 piston is at TDC when TDC mark (M) aligns with tool point.

the following procedure to check and adjust timing.

If engine is installed, turn crankshaft until number 1 piston is on compression and TDC mark on flywheel is aligned with boss on flywheel housing timing window and pump timing marks are aligned. If engine is removed, install adjusting gage, VW tool 2068 (T–Fig. V1-2), on flywheel end of crankcase as shown. Set gage vernier scale to 112.8 mm. Turn crankshaft until number 1 piston is on compression stroke and TDC mark on flywheel is aligned with tip of timing tool (M).

Remove plug from rear of injection pump and install adapter, VW tool 2066, and dial indicator gage as shown in Fig. V1-3. Preload indicator so dial reading is about 2 mm (0.080 inch), then turn flywheel clockwise (opposite normal rotation) until dial needle stops moving. Zero dial gage, then turn flywheel counterclockwise until TDC mark on flywheel is aligned with reference mark. At this point, dial gage reading should be within the range of 0.78-0.88 mm (0.031-0.034 inch) on all naturally aspirated engines or 0.83-0.97 mm (0.033-0.038 inch) on 068.5 turbocharged engines. If plunger lift is not within specified range, loosen fuel pump mounting screws and rotate pump until indicator reading is 0.84-0.88 mm (0.33-0.34 inch) on all naturally aspirated engines or 0.88-0.92 mm (0.034-0.036 inch) on 068.5 turbocharged engines. Retighten pump mounting screws to 25 N·m (18 ft.-lbs.). If necessary scribe new timing marks on pump mounting flange and pump mounting plate. Remove dial gage and adapter. Reinstall plug using a new washer and tighten to 15-25 N·m (11-18 ft.-lbs.).

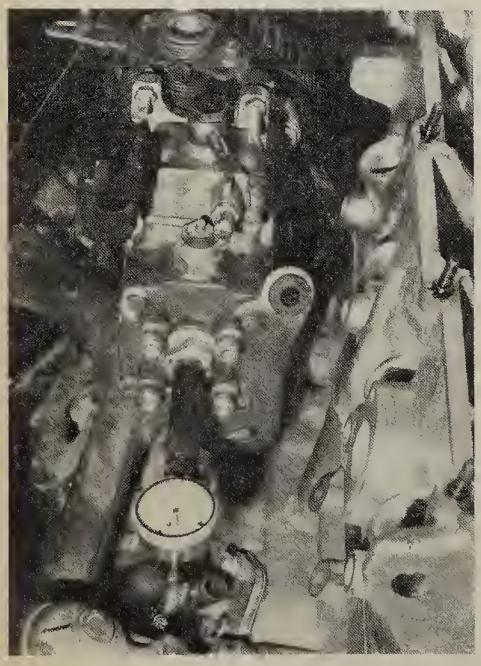


Fig. V1-3—View showing installation of dial gage on injection pump for injection timing. Injection lines may remain connected.

COOLING SYSTEM

The engine is liquid-cooled and equipped with a water pump to circulate coolant. Due to aluminum construction of cylinder head, antifreeze with anticorrosion additives should be used to prevent corrosion.

Water pump belt tension is adjusted by removing pump pulley and adding or removing spacers between pulley halves. Belt tension is correct if thumb pressure deflects belt approximately 10 mm (⅜ inch).

Thermostat should begin to open at 80°C (175°F) and full flow temperature is 91°C (195°F).

REPAIRS

TIGHTENING TORQUES

Refer to the following table for special tightening torques.

Camshaft bearing caps	20 N·m (15 ft.-lbs.)
Camshaft sprocket	45 N·m (33 ft.-lbs.)
Connecting rod	See text
Crankshaft sprocket	See text
Cylinder head	See text
Flywheel	See text
Injection pump	25 N·m (18 ft.-lbs.)
Injection pump sprocket	45 N·m (33 ft.-lbs.)
Injector	70 N·m (51 ft.-lbs.)
Intermediate shaft sprocket	45 N·m (33 ft.-lbs.)
Main bearing	65 N·m (48 ft.-lbs.)
Oil pan	
Sheet metal	20 N·m (15 ft.-lbs.)
Aluminum	10 N·m (8 ft.-lbs.)
Oil pump base	10 N·m (8 ft.-lbs.)
Oil pump mounting screws	20 N·m (15 ft.-lbs.)
Timing belt tension pulley	45 N·m (33 ft.-lbs.)

COMPRESSION PRESSURE

All injectors should be removed when checking compression pressure. Use adapter number V.A.G. 1323/2 in place of injectors on naturally aspirated engines or adapter number V.A.G. 1323/2A on turbocharged engines. At cranking speed, desired compression pressure is 3400 kPa (495 psi) while minimum allowable pressure is 2800 kPa (405 psi). Compression pressure readings among cylinders should not vary more than 500 kPa (73 psi).

Reinstall injectors using new heat shields as outlined in INJECTOR section.

TIMING BELT AND VALVE TIMING

A rubber composition timing belt is used to drive camshaft, injection pump and intermediate shaft. Belt tension is adjusted by loosening tensioner pulley nut and rotating pulley against belt. Use VW tool 210 or other similar tool and adjust belt tension so reading of 12 or 13 is obtained on tool scale.

Use the following procedure for correct valve timing when installing timing belt: Rotate crankshaft so number 1 piston is on compression and top dead center mark (M–Fig. V1-2) on flywheel

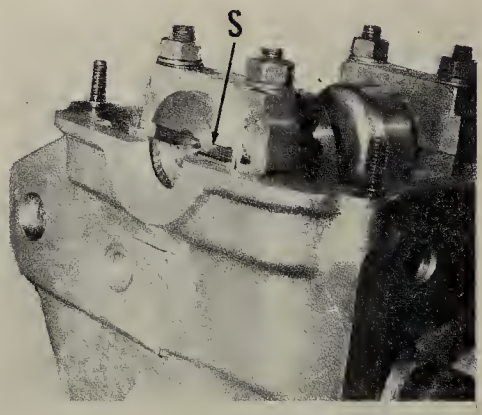


Fig. V1-4—View of slot (S) in rear of camshaft. Number 1 cylinder camshaft lobes point up when slot is correctly positioned for installation of camshaft locking tool.

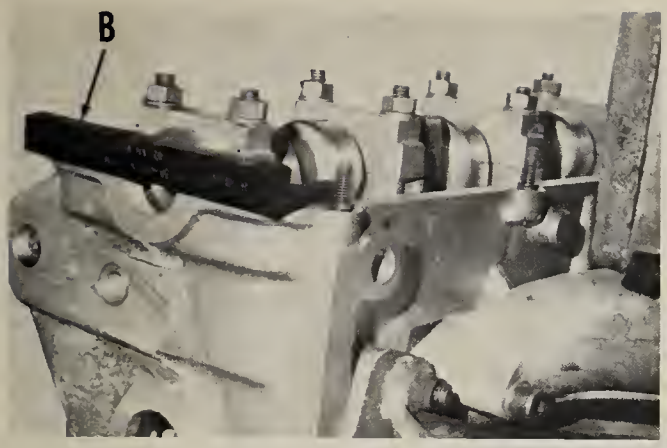


Fig. V1-5—View of camshaft locking tool 2065 (B) engaged in slot (S—Fig. V1-4).

is aligned with pointer of Volkswagen timing tool 2068 (T) or boss on flywheel housing timing window. Camshaft sprocket must be loose on camshaft taper, if not, loosen sprocket retaining screw approximately one-half turn and tap sprocket loose. Loosen and rotate tensioner pulley to maximum slack position. Remove cylinder head cover. Note that camshaft lobes for number 1 cylinder should be pointing up when slot (S – Fig. V1-4) in rear of camshaft is correctly positioned to accept special locking tool bar. Install Volkswagen tool bar 2065 (B – Fig. V1-5) in camshaft slot to lock the shaft and insert lock pin 2064 (T – Fig. V1-6) through sprocket hole and hole in injection pump mounting plate.

Refer to Fig. V1-7 and install timing belt over sprockets and pulleys. Adjust belt tension by rotating tensioner pulley so timing belt tension between camshaft and injection pump sprockets is 12-13 on scale of Volkswagen tension tool 210. Tighten tensioner pulley screw to 45 N·m (33 ft.-lbs.). Tighten camshaft sprocket retaining screw to 45 N·m (33 ft.-lbs.). Remove timing tools, rotate crankshaft several turns and recheck belt tension. Check injection pump timing as outlined in MAINTENANCE section.

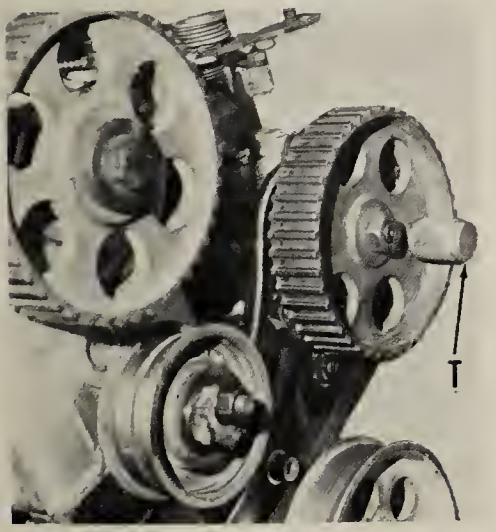


Fig. V1-6—Insert tool 1064 (T) through holes in injection pump sprocket and pump mounting plate.

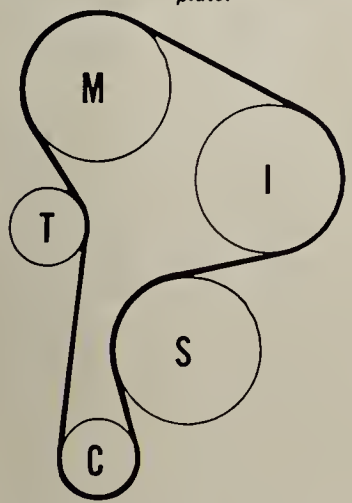


Fig. V1-7—Install timing belt as shown in diagram.

C. Crankshaft sprocket
I. Injection pump sprocket
M. Camshaft sprocket
S. Intermediate shaft pulley
T. Tensioner pulley

VALVE ADJUSTMENT

The camshaft is located in the cylinder head directly above the valves. Gap between camshaft lobe and tappet is adjusted by varying thickness of shim (S – Fig. V1-8) which sits in recess of tappet.

Valve clearance should be measured with engine warm, coolant temperature above 35°C (95°F). Desired clearance is 0.20-0.30 mm (0.008-0.011 inch) for intake and 0.40-0.50 mm (0.016-0.019 inch) for exhaust. However, after performing repairs to valve system or camshaft, valves may be initially adjusted with engine cold using the following clearances: 0.15-0.25 mm (0.006-0.010 inch) for intake and 0.35-0.45 mm (0.014-0.018 inch) for exhaust. After 10 hours of operation, valve clearance must be rechecked and readjusted with engine warm to 0.25 mm (0.010 inch) for intake and 0.45 mm (0.018 inch) for exhaust.

To adjust valve clearance, valve must be depressed using a suitable tool (such as VW 2078) to remove and install shim.

NOTE: Piston of cylinder requiring adjustment must be at least 90° from top dead center to prevent contact between piston and valves.

Insert required thickness shim making certain the side marked with shim thickness is facing downward against tappet.

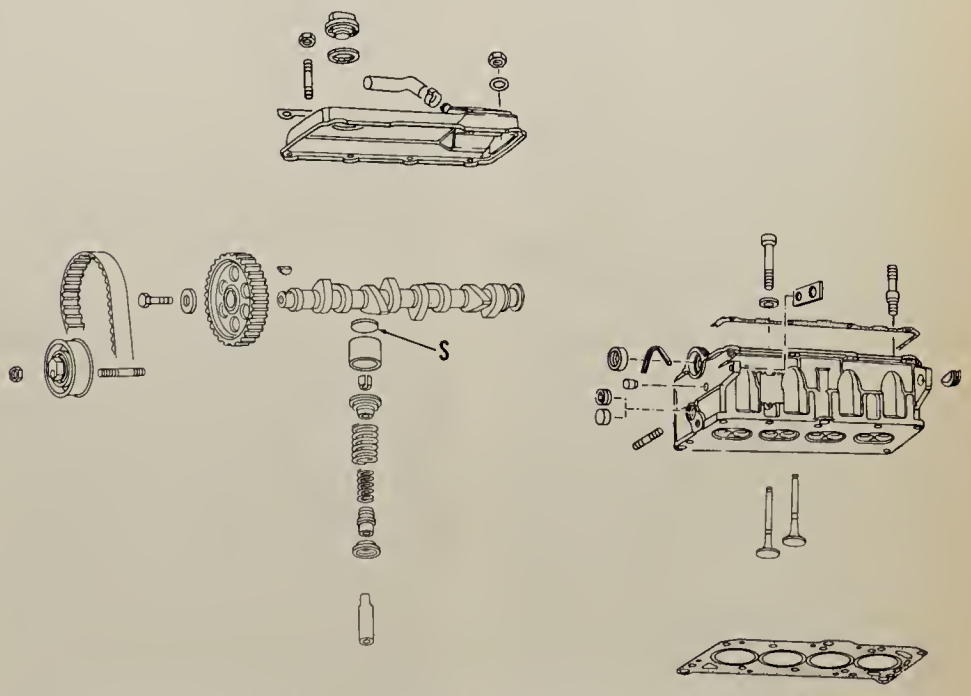


Fig. V1-8—Exploded view of cylinder head assembly. Shim (S) adjusts valve clearance.

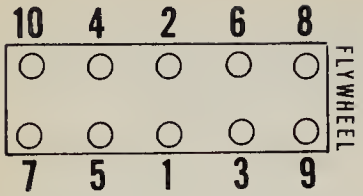


Fig. V1-9—Cylinder head tightening sequence.

CAMSHAFT

REMOVE AND REINSTALL. The camshaft is located in cylinder head and is secured with five caps. To remove camshaft, first remove cylinder head cover and timing belt cover. Rotate crankshaft to position number 1 piston at TDC on compression. Loosen timing belt tensioner and slide belt off camshaft sprocket. Remove camshaft sprocket if necessary. Camshaft retaining caps are numbered 1 through 5 with number 1 nearest sprocket end of camshaft. Remove bearing caps 1, 3 and 5, then using alternate turns in a diagonal pattern, unscrew nuts securing caps 2 and 4 until valve spring pressure is released and camshaft can be removed.

NOTE: If tappets are removed, identify each tappet so they can be reinstalled in their original position. Tappets should not be interchanged.

Special tools are available from Volkswagen to remove and install camshaft oil seal. Tool 2085 is used to remove oil seal and tool 10-203 is used to press new oil seal into cylinder head.

Inspect camshaft, head and caps for excessive wear and damage. Maximum camshaft runout is 0.01 mm (0.0004 inch) measured at center of camshaft with camshaft supported at ends.

Lubricate camshaft journals and bearing surfaces of head and caps prior to assembly. Install camshaft on cylinder head, then place caps numbered 2 and 4 on camshaft but do not tighten nuts.

NOTE: Bearing surface in camshaft retaining caps is offset; be sure cap is installed correctly. Cap numbers 1 through 5 may not be on same side of camshaft.

Alternately tighten in a diagonal pattern nuts securing caps 2 and 4. Install caps 1, 3 and 5 and tighten all nuts to 20 N·m (15 ft.-lbs.). Camshaft end play should not exceed 0.15 mm (0.006 inch). Install camshaft sprocket and tighten retaining screw to 45 N·m (33 ft.-lbs.). Refer to TIMING BELT AND VALVE TIMING section for installation of drive belt. Install cylinder head cover, timing belt cover and air cleaner.

CYLINDER HEAD

REMOVE AND REINSTALL. Drain coolant and detach coolant hoses from cylinder head. Detach timing belt cover, loosen belt tension pulley and remove belt from camshaft sprocket. Remove air cleaner, then disconnect and cap fuel injection lines. Remove cylinder head cover and unscrew cylinder head screws using reverse of sequence shown in Fig. V1-9. Remove camshaft as previously outlined for access to valve components.

Cylinder head surface must not be warped more than 0.1 mm (0.004 inch). Cylinder head must be discarded if head surface distortion is excessive as manufacturer does not recommend machining head surface.

Cylinder head gasket is available in different thicknesses to obtain desired valve-to-piston clearance. Notches on side of gasket (Fig. V1-10) identify different gasket thickness. To select proper cylinder head gasket thickness, measure height of piston above cylinder block surface with piston at TDC. Refer to the following table and install listed gasket.

Piston Height	Gasket Notches
068.2 Engine	
0.43-0.63 mm (0.017-0.025 in.)	2
0.64-0.82 mm (0.025-0.032 in.)	3
0.83-0.92 mm (0.032-0.036 in.)	4
0.93-1.02 mm (0.036-0.040 in.)	5
068.5 Engine	
0.67-0.82 mm (0.026-0.032 in.)	1
0.83-0.92 mm (0.032-0.036 in.)	2
0.93-1.02 mm (0.036-0.040 in.)	3

Before reinstalling cylinder head, turn crankshaft until number 1 piston is at TDC and turn camshaft until cam lobes for number 1 cylinder are pointing upward.

Note that two different cylinder head bolts have been used and a different tightening procedure is used for each type of bolt. On early engines, a M11 hexagon socket head bolt is used. These bolts should be tightened in three steps following the sequence shown in Fig. V1-9. Tighten all bolts in first step to 50 N·m (37 ft-lbs.), in second step to 70 N·m and in third step to 90 N·m (66 ft.-lbs.). Then run engine until warm, coolant temperature above 35°C (95°F), and retorque bolts following the specified sequence to 90 N·m (66 ft.-lbs.). After engine has been in operation about 10 hours, loosen bolts one at a time in specified sequence and retighten to 90 N·m (66 ft.-lbs.).

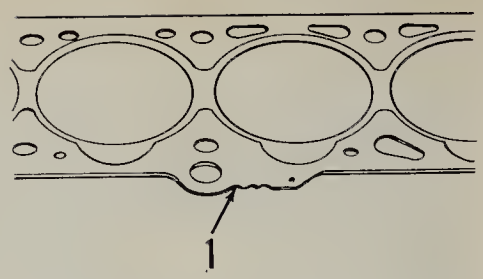


Fig. V1-10—Notches (1) in side of cylinder head gasket identify different thicknesses of gasket. Refer to text.

On late engines, M12 bolts with a 12 point socket head are used.

NOTE: Manufacturer advises that new style M12 bolts should not be reused. Whenever cylinder head is removed, renew the head bolts.

Tighten new style M12 bolts in sequence shown in Fig. V1-9 in three steps as follows: Tighten in first step to 40 N·m (30 ft.-lbs.), in second step to 60 N·m (44 ft.-lbs.) and in third step tighten an additional ½ turn (180°). Operate engine until warm, then tighten each bolt ¼ turn (90°) further following specified sequence. Then, after engine has operated for about 10 hours, tighten each bolt in sequence ¼ turn further with engine either warm or cold.

VALVE SYSTEM

Remove cylinder head and camshaft as previously outlined for access to valve system components. Volkswagen tool 2037 or other suitable tool is used to depress valve spring so valve can be unlocked and removed.

Valves ride in renewable valve guides. Press old guides out towards camshaft side of cylinder head. Cylinder head should be cold and guide lubricated with oil for installation. Press new guide in from camshaft side of head until guide is seated. Do not use excessive force. Ream valve guides to inner diameter of 8.00 mm (0.315 inch) after installation. Valve stem diameter should be 7.97 mm (0.314 inch) for intake and 7.95 mm (0.313 inch) for exhaust.

Valve seat angle is 45° for intake and exhaust. Valve seat width should be 2.0 mm (0.078 inch) for intake and 2.4 mm (0.095 inch) for exhaust. Valve face angle is 45° for intake and exhaust and valve margin should not be less than 0.5 mm (0.020 inch).

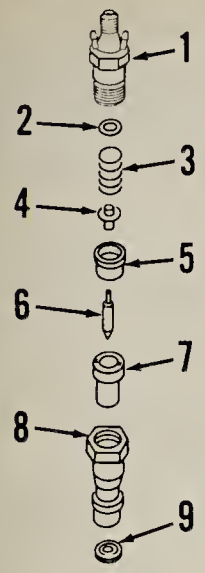


Fig. V1-11—Exploded view of fuel injection nozzle.

1. Body
2. Shim
3. Spring
4. Pressure pin
5. Spacer
6. Valve
7. Nozzle
8. Nozzle nut
9. Heat shield

NOTE: Manufacturer does not recommend refacing the exhaust valves. They should be hand lapped to their seats only.

Valve stem seals should be renewed whenever valve system is serviced. Seals should be installed after valves are positioned in cylinder head. To avoid damage to seals, do not remove valves after new seals are installed. Special tool number 10-204 may be used to install new seals. Be sure to position plastic sleeve over valve stem to protect seal during installation and lubricate seal with oil.

After valves are reinstalled, measure distance valve head is recessed below cylinder head surface. Maximum allowable valve recession is 1.5 mm (0.059 inch).

TURBOCHARGER

Engines So Equipped

TESTING. The turbocharger boost pressure is limited by an integral wastegate to 64-72 kPa (9.3-10.4 psi). An air dump valve is located in the intake manifold to serve as a safety relief valve in case turbocharger boost exceeds it design limits. Air valve is set to open at 76-86 kPa (11.0-12.5 psi).

To check boost pressure, disconnect boost pressure line between intake manifold and injection pump. Connect a pressure gage into boost line using a tee fitting, then reconnect boost line. Boost pressure must be checked with engine at full throttle and rated load.

If boost pressure is too high, wastegate is malfunctioning and turbocharger should be renewed. If boost pressure is too low, disconnect air dump valve hose at air intake and plug hose opening. Repeat boost pressure check. If specified boost pressure is now obtained, air dump valve is defective. If boost pressure is still low and all other engine and injection pump settings are satisfactory, turocharger is defective and should be renewed.

REMOVE AND REINSTALL. Thoroughly clean turbocharger and surrounding area prior to removal. Disconnect oil supply line and oil return line. Remove air inlet and discharge hoses. Remove cap screws securing turbocharger to exhaust pipe and manifold and withdraw turbocharger.

Manufacturer does not recommend rebuilding turbocharger. If defective, complete turbocharger should be renewed.

To reinstall turbocharger, reverse the removal procedure. Before reconnecting oil supply hose, fill turbocharger oil inlet with oil to ensure initial start-up lubrication. When first started, operate engine at low speed for about one minute to allow oil to circulate to turbocharger.

INJECTOR

WARNING: Fuel emerges from injector with sufficient force to penetrate the skin. When testing injector, keep yourself clear of nozzle spray.

REMOVE AND REINSTALL. Before removing an injector or loosening injector lines, thoroughly clean injector, lines and adjacent area with a suitable solvent and compressed air. Disconnect high pressure and bypass lines from injector, then cap lines to prevent contamination. Unscrew injector from cylinder head, then remove and discard heat shield (9 – Fig. V1-11).

Before installing injector, be sure injector bore and seating surface in head are clean and free of carbon. Install new heat shield (9) with concave side towards combustion chamber as shown in Fig. V1-12. Install injector and tighten to 70 N·m (51 ft.-lbs.). Reconnect injector lines.

TESTING. A complete job of testing and adjusting injectors requires use of special test equipment. Only clean, approved testing oil should be used to test injectors. Injector nozzle should be tested for opening pressure and seat leakage. When operating properly during test, injector nozzle will emit a buzzing sound and cut off quickly with no fluid leakage at seat.

Before conducting test, operate tester lever until test oil flows, then attach injector. Close valve to tester gage and pump tester lever a few quick strokes to

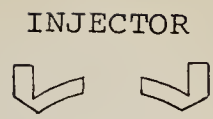


Fig. V1-12—Install injector heat shield so concave side is toward combustion chamber.

be sure nozzle valve is not stuck, which would indicate that injector may be serviceable without disassembly.

OPENING PRESSURE. Open valve to tester gage and operate tester lever slowly while observing gage reading. Opening pressure for new injectors is 13000-13800 kPa (1885-2000 psi) for naturally aspirated engines, or 15500-16300 kPa (2250-2365 psi) for turbocharged engines. Minimum allowable opening pressure for used injectors is 12000 kPa (1740 psi) on naturally aspirated engines, or 14000 kPa (2030 psi) on turbocharged engines.

Opening pressure is adjusted by varying thickness of shim (2 – Fig. V1-11). Increasing or decreasing shim thickness by 0.5 mm (0.020 inch) will change opening pressure approximately 500 kPa (70 psi). When servicing injectors, set opening pressure to new injector specification.

SEAT LEAKAGE. Injector nozzle tip should not leak at a pressure less than 11000 kPa (1560 psi). To check for leakage, actuate tester lever slowly and as gage needle approaches suggested test pressure, observe nozzle tip. Hold pressure for 10 seconds; if drops appear or nozzle tip becomes wet, valve is not seating and injector must be disassembled and overhauled as later outlined.

OVERHAUL. Hard or sharp tools, emery cloth, grinding compound or other than approved solvents or lapping compounds must never be used. An approved nozzle cleaning kit is available through a number of specialized sources.

Wipe all dirt and loose carbon from exterior of nozzle and holder assembly. Refer to Fig. V1-11 for exploded view and proceed as follows:

Secure injector body (1) in a soft jawed vise or holding fixture and remove nozzle nut (8). Place all parts in clean calibrating oil or diesel fuel as they are removed, using a compartmented pan and using extra care to keep parts from each injector together and separate from other units.

Clean exterior surfaces with a brass wire brush, soaking in an approved carbon solvent, if necessary, to loosen hard carbon deposits. Rinse parts in clean diesel fuel or calibrating oil immediately

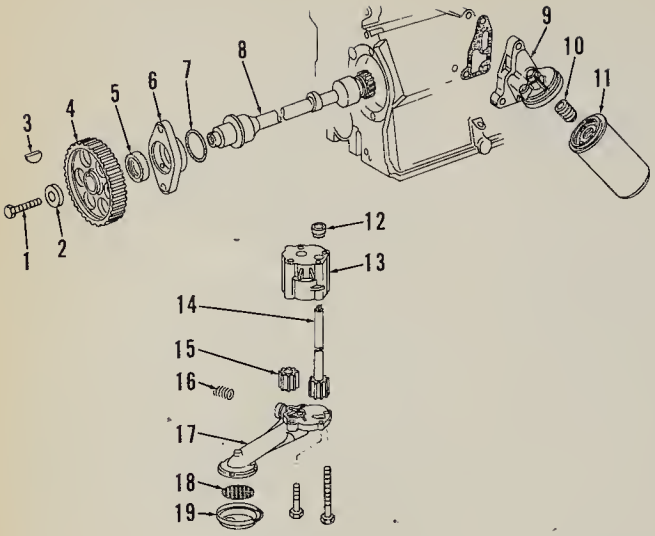


Fig. V1-13—Exploded view of intermediate shaft and oil pump assemblies.

1. Screw
2. Washer
3. Key
4. Sprocket
5. Seal
6. Carrier
7. "O" ring
8. Intermediate shaft
9. Filter mount
10. Nipple
11. Oil filter
12. Bushing
13. Pump body
14. Drive shaft & gear
15. Driven gear
16. Relief spring
17. Pickup
18. Screen
19. Cap

after cleaning to neutralize the solvent and prevent etching of polished surfaces. Make certain nozzle valve (6) slides freely in nozzle body (7). If valve sticks, reclean or renew nozzle valve assembly.

Reassemble injector while wet with diesel fuel. Tighten nozzle nut (8) and upper body (1) to 70 N·m (51 ft.-lbs.). Retest injector as outlined in TESTING paragraphs.

GLOW PLUGS

Each cylinder is equipped with a glow plug. Glow plugs are connected in parallel with each glow plug grounded through mounting threads. Before suspecting a glow plug malfunction, determine that current is reaching glow plugs. To check individual glow plugs, remove electrical strap between glow plugs. With negative battery terminal grounded to engine, connect a test light between positive battery terminal and glow plug electrode. If test light turns on, the glow plug is good. If test light remains off, then glow plug is defective and must be renewed.

INJECTION PUMP

Refer to Fig. V1-1 for view of injection pump. The injection pump should be tested and overhauled by a shop qualified in diesel injection pump repair.

To remove injection pump, disconnect fuel lines and cap openings to prevent contamination. Disconnect control cables. Detach timing belt cover, loosen belt tensioner pulley and slide timing belt off injection pump sprocket. Using a suitable puller, remove sprocket from pump shaft. Remove pump retaining screws and remove pump.

When installing, tighten pump retaining screws to 25 N·m (18 ft.-lbs.) and sprocket nut to 45 N·m (33 ft.-lbs.). Refer to TIMING BELT AND VALVE TIMING section to install timing belt and to INJECTION PUMP TIMING section for pump timing. Refer to ENGINE SPEED ADJUSTMENT section if idle or high engine speed requires adjustment.

OIL PUMP

R&R AND OVERHAUL. The oil pump is driven by intermediate shaft (8–Fig. V1-13) gear and a gear coupled to oil pump drive shaft (14). To remove oil pump, remove oil pan and unscrew oil pump mounting screws.

Remove oil pump base and pickup (17). Backlash between pump gears should be 0.05-0.20 mm (0.002-0.008 inch). Place a straightedge across face of body and measure gap between straightedge and ends of gears. Maximum allowable gap is 0.15 mm (0.006 inch).

Tighten oil pump base screws to 10 N·m (8 ft.-lbs.). Install pump and tighten pump mounting screws to 20 N·m (15 ft.-lbs.).

PISTON AND ROD UNITS

REMOVE AND REINSTALL. Piston and connecting rod are removed as a unit after removing cylinder head and oil pan. Unscrew rod cap retaining nuts, detach rod cap and extract piston and rod.

NOTE: Connecting rod and cap are a matched pair. Be sure to place mating marks on each rod and cap so they can be correctly reinstalled. Mark cylinder numbers on pistons so they can be reinstalled in their original location.

Marks (M–Fig. V1-16) cast in rod and cap must be on same side when installing cap on rod. Install piston and rod units so marks (M) are nearer intermediate shaft side of engine and arrow on piston crown points towards crankshaft pulley end.

NOTE: Late model engines are equipped with stretch type connecting rod bolts instead of rigid bolts used on early engines. Refer to Fig. V1-14. Stretch type bolts should not be reused. Bolts must be renewed whenever connecting rods are removed.

Lubricate connecting rod nuts with oil prior to installation. On early style rigid type connecting rod bolts, tighten nuts to 45 N·m (33 ft.-lbs.). If equipped with stretch type bolts, tighten nuts to 30 N·m (22 ft.-lbs.) then turn nut an additional ½ turn (180°).

If new pistons or connecting rods are installed, refer to CYLINDER HEAD section and determine required head gasket thickness.

PISTON, PIN AND RINGS

All pistons are equipped with two compression rings and an oil control ring. Oversize pistons and rings are available.

Clearance between piston and cylinder bore should be 0.03 mm (0.0012 inch). Measure piston diameter approximately 15 mm (19/32 inch) from bottom of piston skirt and perpendicular to piston pin. Standard piston diameter is 76.48 mm (3.011 inch). Renew piston if wear exceeds 0.04 mm (0.0016 inch). Standard cylinder bore is 76.51 mm (3.012 inch). If cylinder wear exceeds 0.08 mm (0.003 inch), rebore and install next appropriate oversize piston and rings.

Piston ring end gap is 0.3-0.5 mm (0.012-0.019 inch) for compression rings and 0.25-0.40 mm (0.010-0.015 inch) for oil ring. Maximum allowable end gap is

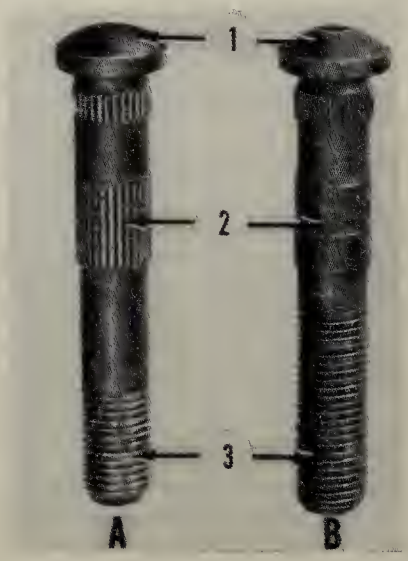


Fig. V1-14—On early engines, a rigid type bolt (A) is used to secure connecting rod cap. A stretch type bolt (B) is used on late engines. Stretch type bolt has a cone shaped head (1), a smooth center section (2) and increased thread length (3). Refer to text for tightening procedure.

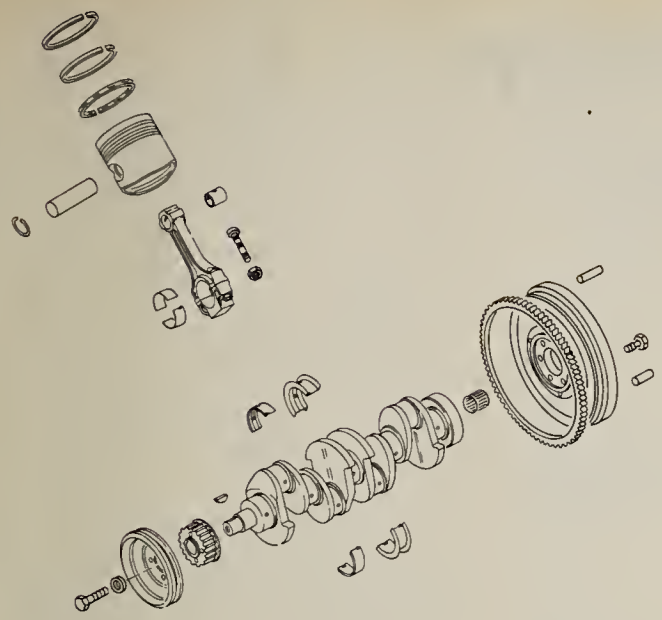


Fig. V1-15—Exploded view of crankshaft, piston and rod assemblies.

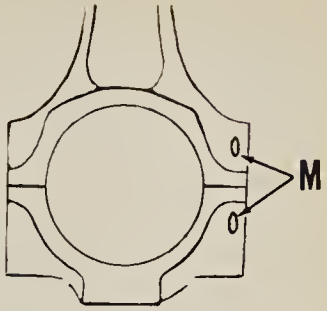


Fig. V1-16—Connecting rod marks (M) must be on same side as shown.

1.0 mm (0.039 inch) for any ring. Side clearance is 0.06-0.09 mm (0.0024-0.0035 inch) for top compression ring, 0.05-0.08 mm (0.0020-0.0031 inch) for second compression ring and 0.03-0.06 mm (0.0012-0.0024 inch) for oil ring. Maximum allowable side clearance is 0.2 mm (0.008 inch) for compression rings and 0.15 mm (0.006 inch) for oil ring.

When reinstalling rings onto piston, note "TOP" marks on rings and install accordingly. Stagger ring end gaps 120 degrees apart.

The piston pin is full floating type and retained by snap rings in piston. Piston pin removal and installation is eased if piston is first heated to approximately 60°C (140°).

CONNECTING ROD AND BEARINGS

Connecting rod is equipped with a renewable bushing in the small end and insert type bearings in the big end. Clearance between rod bearing and crankpin should be 0.028-0.088 mm (0.0011-0.0035 inch). Maximum bearing clearance is 0.12 mm (0.005 inch). Maximum rod side play is 0.37 mm (0.0145 inch).

CRANKSHAFT AND BEARINGS

R&R AND OVERHAUL. To remove crankshaft, drain coolant then remove water pump and, if so equipped, alternator and starter. Remove fuel injection pump, cylinder head and piston and rod units. Remove crankshaft V-belt pulley and timing belt sprocket. Remove flywheel and seal carriers at both ends of crankshaft. The crankshaft can be removed after detaching main bearing caps.

Main bearing clearance is 0.03-0.08 mm (0.0012-0.0031 inch) with a maximum limit of 0.17 mm (0.0067 inch). Crankshaft end play is 0.07-0.17 mm (0.0028-0.0067 inch) with a maximum limit of 0.37 mm (0.0145 inch). Crankshaft end play is controlled by center main bearing.

Standard diameter of crankpin is 45.958-45.978 mm (1.8094-1.8101 inches) for 068.2 engines and 47.758-47.778 mm (1.8802-1.8810 inches) for 068.5 engines. Standard main journal diameter is 53.958-53.978 mm (2.1243-2.1251 inches) for all engines. Undersize bearings are available.

To reinstall crankshaft, reverse the removal procedure. On early engines, crankshaft sprocket was located on crankshaft by Woodruff key and a M12 x 1.5 cap screw. On these engines, apply thread locking compound to cap screw and tighten to 80 N·m (60 ft.-lbs.). On late engines, sprocket is located on crankshaft by a notch in the end of the shaft and a lug on the sprocket which engages the slot. Sprocket retaining cap screw is M14x1.5 Durlock screw which should be tightened (with threads oiled) to 200 N·m (148 ft.-lbs.). Some engines are equipped with a front pto drive. On these engines, sprocket is not keyed to crankshaft. Sprocket is secured to crankshaft with a thrust ring and two sets of clamping rings. When installing, apply thread locking compound to cap screw threads and tighten to 85 N·m (63 ft.-lbs.). Note that engine timing will be affected on these engines if sprocket cap screw is accidentally loosened and sprocket moves on crankshaft.

Refer to TIMING BELT AND VALVE TIMING section to install timing belt and to INJECTION PUMP TIMING section for pump timing.

CRANKSHAFT SEALS

Crankshaft seals are located in seal carriers which are attached to front and rear of cylinder block. Seals may be renewed without detaching seal carriers, however, if seal carriers must be removed, note that two screws in each end of oil pan are threaded into seal carriers. Be sure to lubricate lip of oil seals with clean oil before installing over crankshaft.

FLYWHEEL AND CLUTCH

When removing clutch (if so equipped), loosen mounting cap screws in a diagonal pattern. Inspect pressure plate diaphragm spring ends for excessive wear. Check pressure plate friction surface for cracks, wear or other damage. Renew pressure plate assembly if friction surface is warped more than 0.3 mm (0.012 inch). Check clutch disc for wear or other damage. Renew clutch disc if friction material rivets are loose. Maximum allowable clutch disc runout is 0.4 mm (0.016 inch). Check clutch disc splines for excessive wear.

Check pilot bearing in crankshaft flange for rough operation or damage. Install new bearing with lettered side facing outward. Press in until 1.5 mm (0.060 inch) below outer surface of flywheel hub.

Early flywheels were retained by cap screws without a shoulder while late engines use cap screws with a shoulder to secure flywheel. Manufacturer recommends installing new cap screws whenever flywheel is removed. Apply thread locking compound to cap screws and tighten to 100 N·m (74 ft.-lbs.).

When reinstalling clutch assembly, use a pilot shaft to align clutch disc. Tighten pressure plate mounting screws using a diagonal pattern to 25 N·m (18 ft.-lbs.).

WISCONSIN

TELEDYNE WISCONSIN MOTOR
1910 S. 53rd Street
Milwaukee, Wisconsin 53219

Model	No. Cyls.	Bore	Stroke	Displ.
WD1-340	1	75 mm (2.953 in.)	78 mm (3.701 in.)	345 cc (21 cu. in.)
WD1-350	1	75 mm (2.953 in.)	78 mm (3.071 in.)	345 cc (21 cu. in.)
WD1-430	1	84 mm (3.307 in.)	78 mm (3.071 in.)	432 cc (26.3 cu. in.)
WD1-430	1	84 mm (3.307 in.)	78 mm (3.071 in.)	432 cc (26.3 cu. in.)
WD1-660	1	95 mm (3.740 in.)	95 mm (3.740 in.)	673 cc (41 cu. in.)
WD1-670	1	95 mm (3.740 in.)	95 mm (3.740 in.)	673 cc (41 cu. in.)
WD1-750	1	100 mm (3.937 in.)	95 mm (3.740 in.)	746 cc (45.5 cu. in.)

Engines covered in this section are air-cooled, single-cylinder, four-stroke diesel engines. Crankshaft rotation is counterclockwise at pto end. Metric fasteners are used throughout the engine.

MAINTENANCE

LUBRICATION

Recommended engine oil is SAE 10W or 5W-20 for temperatures below minus 18°C (0°F), SAE 10W or 10W-30 for temperatures between minus 18°C (0°F) and 0°C (32°F), SAE 20 or 15W-40 for temperatures between 0°C (32°F) and 20°C (68°F) and SAE 40 or 15W-40 for temperatures above 20°C (68°F). API oil classification should be CD. Oil sump capacity is 0.95 liters (1 quart) for Models WD1-340, WD1-350 and WD1-430 or 2.8 liters (3 quarts) for all other engines. Manufacturer recommends renewing oil after every 100 hours of operation. Oil should be drained while engine is hot.

A reusable oil filter element is mounted internally on the oil pickup tube (P–Fig. W1-1). manufacturer recommends cleaning filter element after every 200 hours of operation. Renew element if damaged or if it cannot be cleaned. An externally mounted filter element is also used on WD1-660, WD1-670 and WD1-750 engines. Filter element should be renewed after every 200 hours of operation.

ENGINE SPEED ADJUSTMENT

Idle speed is adjusted by turning idle speed screw (I–Fig. W1-2) and high speed is adjusted by turning high speed screw (H). Idle speed should be 1500-1800 rpm while maximum governed speed under load may be 2200 or 3000 rpm depending on engine application.

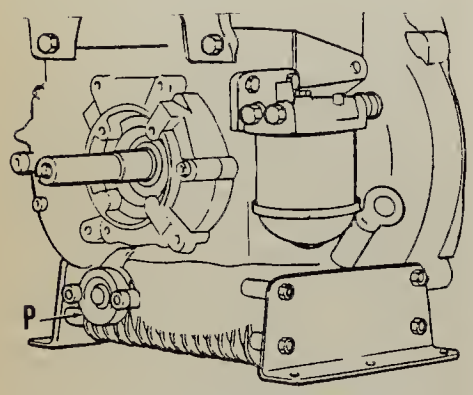


Fig. W1-1—Remove oil pickup (P) for access to internal oil filter.

FUEL SYSTEM

FUEL FILTERS. A fuel filter is located in the fuel tank on all models and some engines may be equipped with an external fuel filter. Renew fuel filters after every 200 hours of operation or sooner if required.

BLEED FUEL SYSTEM. On gravity-feed fuel systems, a fuel return line and check valve are connected to the fuel injection pump as well as the fuel supply line. Fuel supply line should bleed air automatically up to fuel injection pump on gravity flow systems. To bleed high pressure injection line, loosen fitting for high pressure line at injector, then rotate engine crankshaft to operate fuel injection pump until air-free fuel flows from injection line. Retighten injection line.

On engines equipped with a fuel transfer pump, loosen fuel supply line fitting on injection pump, then rotate engine crankshaft to operate fuel transfer pump until air-free fuel flows from fuel line. Retighten fuel supply line and loosen fitting for high pressure injection line at injector. Rotate engine crankshaft to operate fuel injection pump until air-free fuel flows from injection line. Retighten injection line.

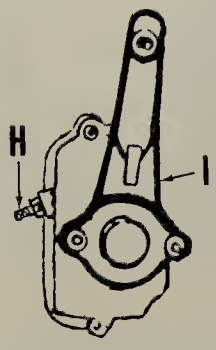


Fig. W1-2—View showing location of high speed adjusting screw (H). Idle speed screw is located behind speed control lever at (I).

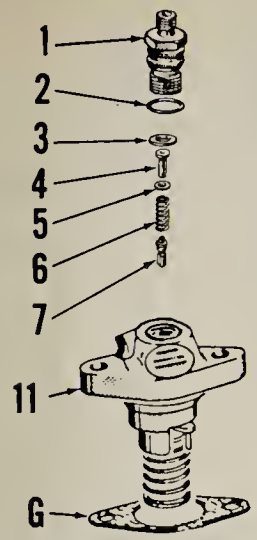


Fig. W1-3—Partial exploded view of fuel injection pump. Injection timing is adjusted using shim gaskets (G).

1. Delivery valve holder
2. "O" ring
3. Gasket
4. Spring guide
5. Shim
6. Spring
7. Delivery valve
11. Fuel injection pump

INJECTION PUMP TIMING

Injection pump timing is adjusted using shim gaskets (G–Fig. W1-3) between pump body and mounting surface of crankcase. Refer to INJECTION PUMP section for pump removal and installation.

To check injection pump timing, unscrew high pressure injection line from injection pump delivery valve holder (1). Unscrew delivery valve holder (1) and remove spring (6), shim (5), spring guide (4) and delivery valve (7), then screw delivery valve holder (1) back into pump. Move throttle control to full speed position. Rotate engine in normal direction (counterclockwise at pto) so piston is on compression stroke. Fuel will flow out of delivery valve holder–it may be necessary to connect a gravity-flow fuel tank to injection pump if engine is not so equipped. Stop engine rotation at moment fuel ceases to flow. Timing mark (R–Fig. W1-4) should be within 3 mm (⅛ inch) of injection timing mark (N) on crankcase. To advance injection timing, remove shim gaskets (G–Fig. W1-3); install shim gaskets to retard injection timing. Reinstall removed pump parts after checking timing.

REPAIRS

TIGHTENING TORQUES

Refer to the following table for special tightening torques. All fasteners are metric.

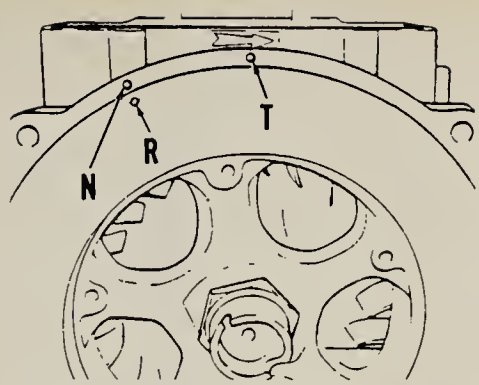


Fig. W1-4—Fuel injection should occur when flywheel reference mark (R) is aligned with crankcase mark (N). The piston is at top dead center when flywheel mark (R) is aligned with crankcase mark (T).

WD1-340, WD1-350 and WD1-430

Connecting rod	34 N·m (25 ft.-lbs.)
Crankcase	30 N·m (22 ft.-lbs.)
Cylinder head	44 N·m (33 ft.-lbs.)
Fan	16 N·m (12 ft.-lbs.)
Flywheel	176 N·m (130 ft.-lbs.)
Gear cover	25 N·m (18 ft.-lbs.)
Injection pump	25 N·m (18 ft.-lbs.)
Injection retainer plate	10 N·m (7 ft.-lbs.)

WD1-660, WD1-670 and WD1-750

Connecting rod	49 N·m (36 ft.-lbs.)
Crankcase	
M8	30 N·m (22 ft.-lbs.)
M12	69 N·m (51 ft.-lbs.)
Cylinder head	69 N·m (51 ft.-lbs.)
Fan	16 N·m (12 ft.-lbs.)
Flywheel	588 N·m (434 ft.-lbs.)
Gear cover	25 N·m (18 ft.-lbs.)
Injection pump	30 N·m (22 ft.-lbs.)
Injection retainer plate	10 N·m (7 ft.-lbs.)

VALVE ADJUSTMENT

Manufacturer recommends checking valve clearance after every 200 hours of operation. Valve clearance may be adjusted after removing rocker arm cover and turning crankshaft to position piston at TDC on compression stroke.

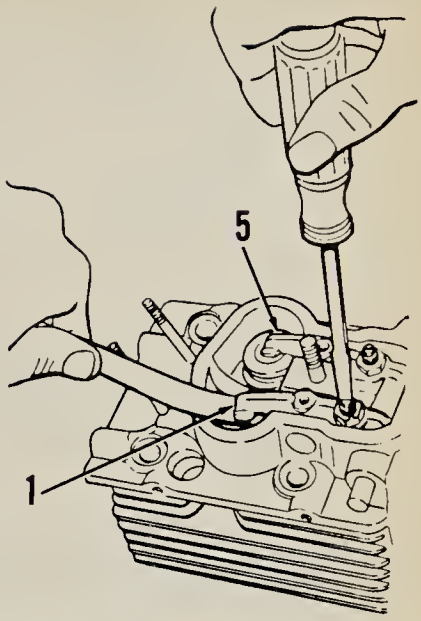


Fig. W1-5—Refer to text for adjustment of exhaust (1) and intake (5) valve clearance.

Turn rocker arm adjusting screw (Fig. W1-5) until appropriate size feeler gage can be inserted between rocker arm and valve stem end. Recommended clearance with engine cold is 0.010 mm (0.004 inch) for intake and 0.15 mm (0.006 inch) for exhaust on WD1-340, WD1-350 and WD1-430, or 0.20 mm (0.008 inch) for both valves on WD1-660, WD1-670 and WD1-750 engines.

CYLINDER HEAD AND VALVE SYSTEM

R&R AND OVERHAUL. To remove cylinder head, disconnect high pressure and return fuel injection lines, then immediately cap fuel lines. Remove muffler, air cleaner, exhaust and intake manifolds. Remove rocker arm cover, unscrew cylinder head retaining nuts and remove cylinder head.

Valve face angle for both valves is 45½ degrees and valve seat angle is 45 degrees. Valve seats are renewable and must be installed with head heated to 200°C (392°F). There should be an interference fit of 0.079-0.120 mm (0.0031-0.0047 inch) between seat insert and cylinder head counterbore on WD1-340, WD1-350 and WD1-430 engines, or 0.127-0.159 mm (0.0050-0.0063 inch) on WD1-660, WD1-670 and WD1-750 engines. Renew valve if head margin is less than 0.6 mm (0.024 inch). With valves installed, top of valve heads should be recessed 0.60-0.95 mm (0.024-0.037 inch) below surface of cylinder head.

On WD1-340, WD1-350 and WD1-430 engines, valve stem diameter is 6.945-6.960 mm (0.2734-0.2740 inch). Valve guide inner diameter is

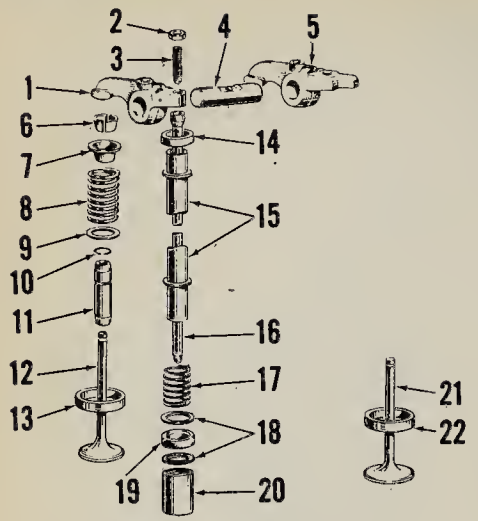


Fig. W1-6—Exploded view of valve train. On Models WD1-660, WD1-670 and WD1-750, an inner spring is located inside valve spring (8) and snap ring (10) is not used.

1. Exhaust rocker arm
2. Locknut
3. Adjuster
4. Rocker arm shaft
5. Intake rocker arm
6. Keys
7. Spring retainer
8. Valve spring
9. Washer
10. Snap ring
11. Valve guide
12. Exhaust valve
13. Exhaust valve seat
14. Seal
15. Push rod tube
16. Push rod
17. Spring
18. Washer
19. Seal
20. Cam follower
21. Intake valve
22. Intake valve seat

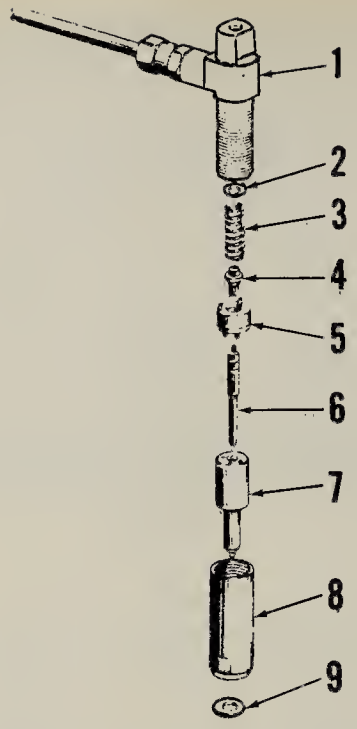


Fig. W1-7—Exploded view of injector.

1. Body
2. Shim
3. Spring
4. Push piece
5. Spacer
6. Valve
7. Nozzle
8. Nozzle holder
9. Gasket

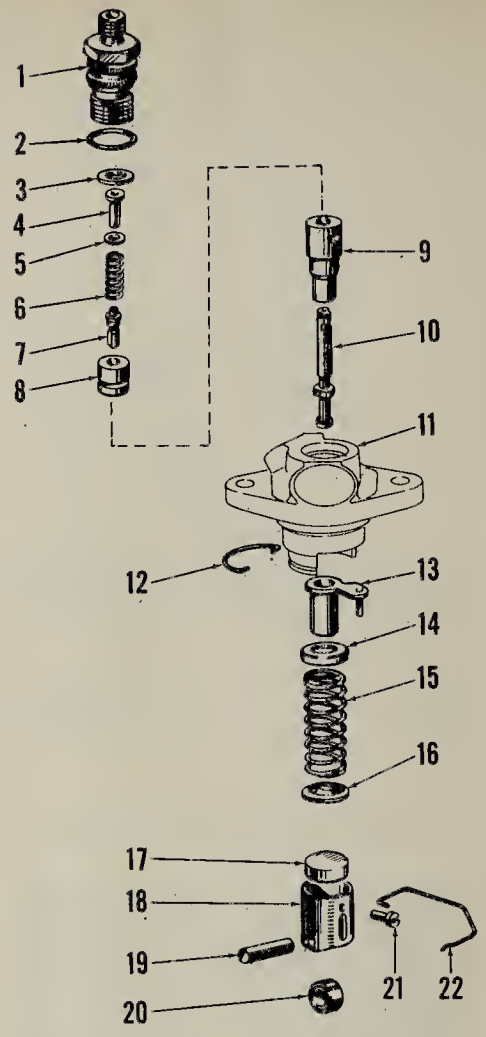


Fig. W1-8—Exploded view of fuel injection pump.

1. Delivery valve holder
2. "O" ring
3. Gasket
4. Spring guide
5. Shim
6. Spring
7. Delivery valve
8. Delivery valve seat
9. Barrel
10. Plunger
11. Body
12. Clip
13. Control sleeve
14. Spring seat
15. Spring
16. Spring retainer
17. Spacer
18. Tappet
19. Pin
20. Roller
21. Pin
22. Clip

7.000-7.015 mm (0.2756-0.2762 inch). Valve stem-to-guide clearance should be 0.040-0.070 mm (0.0016-0.0028 inch) with a wear limit of 0.2 mm (0.008 inch).

Valve guides are renewable. Heat cylinder head to 200°C (392°F) when removing or installing valve guides. To remove valve guide, press guide out top of cylinder head. When installing valve guide, note that guide may have a locating flange or a snap ring (10–Fig. W1-6). Press guide into head from rocker arm side of head so guide flange bottoms or snap ring seats in groove.

Reassemble by reversing disassembly procedure. Install new "O" rings on compression release shaft. Install new upper seals on push rod tubes. Tighten cylinder head nuts to 69 N·m (51 ft.-lbs.).

INJECTOR

REMOVE AND REINSTALL. To remove injector, first clean dirt from injector, injection line, return line and cylinder head. Disconnect return line and high pressure injection line and immediately cap or plug all openings. Unscrew retainer plate and remove injector and copper washer.

Reverse removal procedure to reinstall injector. Install a new copper washer (9–Fig. W1-7). Tighten injector retaining plate nuts to 10 N·m (7 ft.-lbs.).

TESTING. A suitable test stand is required to check injector operation. Only clean, approved testing oil should be used to test injector.

WARNING: Fuel leaves the injection nozzle with sufficient force to penetrate the skin. When testing, keep yourself clear of nozzle spray.

Attach injector to tester and operate pump lever a few quick strokes to purge air from injector and to make sure nozzle valve is not stuck. When operating properly during test, injector nozzle will emit a buzzing sound and cut off quickly with no leakage at seat. Spray pattern should be uniform and well atomized.

Opening pressure on WD1-340, WD1-350 and WD1-430 should be 20100-21085 kPa (2915-3055 psi). Opening pressure on WD1-660, WD1-670 and WD1-750 should be 24025-25000 kPa (3485-3625 psi). Opening pressure is adjusted by varying the thickness of shims (2–Fig. W1-7).

Operate tester to maintain a pressure of 17600 kPa (2550 psi). If a drop forms at nozzle tip within ten seconds, nozzle valve is not seating and injector must be overhauled or renewed.

OVERHAUL. Clamp injector body (1–Fig. W1-7) in a vise with nozzle pointing upward, unscrew nozzle holder nut (8) then remove injector components shown in Fig. W1-7. Thoroughly clean all parts in a suitable solvent. Clean inside orifice of nozzle tip with a wooden cleaning stick. When reassembling injector, make certain all components are clean and wet with clean diesel fuel oil. Tighten nozzle holder nut (8) to 49 N·m (36 ft.-lbs.).

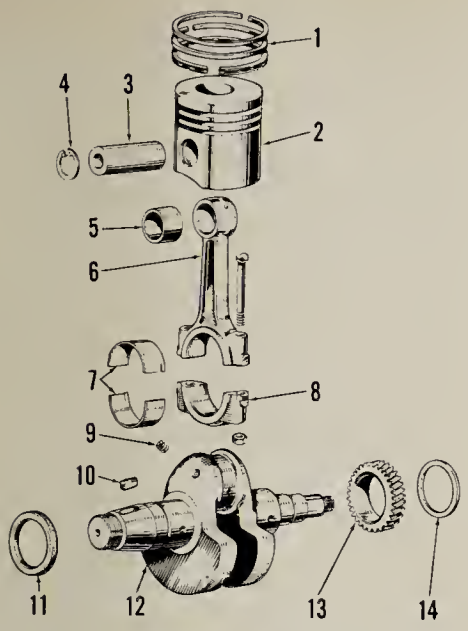


Fig. W1-9—Exploded view of crankshaft assembly.

1. Piston rings
2. Piston
3. Piston pin
4. Snap ring
5. Bushing
6. Connecting rod
7. Bearing
8. Rod cap
9. Plug
10. Key
11. Rubber ring
12. Crankshaft
13. Gear
14. Thrust washer

INJECTION PUMP

R&R AND OVERHAUL. To remove fuel injection pump, disconnect fuel lines and immediately cap all openings. Refer to GOVERNOR section and detach side control cover. Unscrew pump retaining screws and remove fuel injection pump. Do not lose shim gaskets (G–Fig. W1-3). Pump components (17 through 22–Fig. W1-8) will remain in crankcase. If tappet assembly must be removed, reach inside side cover opening and place a magnet against guide pin (21). Detach clip (22) and use magnet to remove guide pin (21). Slide tappet (18) out of crankcase.

Refer to Fig. W1-8 for an exploded view of fuel injection pump. The injection pump should be tested and overhauled by a shop qualified in diesel fuel injection pump repair.

Reverse removal procedure to reinstall pump. Tighten pump retaining screws to 25 N·m (18 ft.-lbs.) on Models WD1-340, WD1-350 and WD1-430 or to 30 N·m (22 ft.-lbs.) on all other models. If pump is renewed or overhauled, or original shim gaskets are not used, refer to INJECTION PUMP TIMING section and adjust pump timing.

PISTON, PIN, RINGS AND CYLINDER

R&R AND OVERHAUL. Remove cylinder head as previously outlined. If piston and cylinder do not require service but only removal, proceed as follows: Rotate crankshaft so piston is at top dead center. Lift cylinder up until piston pin is exposed, remove piston pin retainer, withdraw piston pin and remove cylinder and piston as a unit. If piston, rings or cylinder requires service, lift cylinder off crankcase, remove piston pin retainer, withdraw piston pin and remove piston.

Check cylinder bore for excessive wear or other damage. If cylinder taper or out-of-round exceeds 0.15 mm (0.006 inch), cylinder should be rebored and fitted with 0.5 mm (0.020 inch) or 1.0 mm (0.040 inch) oversize piston and rings.

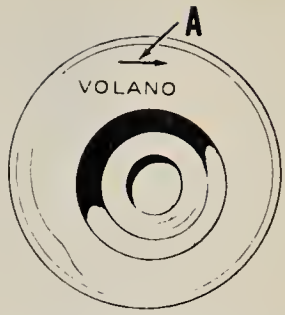


Fig. W1-10—Arrow (A) on piston crown must point towards flywheel.

Piston diameter is measured 12 mm (½ inch) from bottom of piston skirt on WD1-340, WD1-350 and WD1-430 or 18 mm (¾ inch) from bottom of skirt on all other engines. Standard pistons and cylinders are coded and matched according to size. Pistons are stamped with an A or B and cylinders are color coded with a red or yellow or a blue or green paint dot on outside of cylinder barrel. Refer to Table 1 for piston and corresponding cylinder sizes. Maximum allowable clearance between piston and cylinder is 0.2 mm (0.008 inch).

Check piston ring end gap with ring positioned squarely in cylinder bore. On WD1-340, WD1-350 and WD1-430 engines, recommended end gap is 0.25-0.40 mm (0.010-0.016 inch) for top ring, 0.30-0.45 mm (0.012-0.018 inch for center ring and 0.25-0.40 mm (0.010-0.016 inch) for oil control ring. On WD-660, WD1-670 and WD-750 engines, ring end gap should be 0.35-0.55 mm (0.014-0.022 inch) for both compression rings and 0.25-0.40 mm (0.010-0.016 inch) for oil control ring.

Check side clearance of rings in their respective grooves with a feeler gage. On WD1-340, WD1-350 and WD1-430 engines, recommended side clearance is 0.050-0.082 mm (0.002-0.003 inch) for center ring and 0.040-0.072 mm (0.0016-0.0028 inch) for oil control ring. Maximum allowable side clearance is 0.15 mm (0.006 inch) for center ring and 0.13 mm (0.005 inch) for oil control ring. On WD1-660, WD1-670 and WD1-750 engines, groove side clearance should be 0.072-0.100 mm (0.0028-0.0040 inch) for center ring and 0.040-0.072 mm (0.0015-0.0028 inch) for oil control ring. Maximum allowable clearance is 0.25 mm (0.010 inch) for all rings.

Piston pin clearance in rod bushing should be 0.02-0.04 mm (0.0008-0.0016 inch) with a wear limit of 0.10 mm (0.004

TABLE 1—Standard piston and cylinder matching codes and dimensions.

Model	Code	Piston O.D.	Cylinder I.D.
WD1-340, WD1-350	A Red or Yel B Blue or Grn	74.930 - 74.940 mm (2.9500 - 2.9504 in.) 74.940 - 74.950 mm (2.9504 - 2.9508 in.)	75.000 - 75.010 mm (2.9527 - 2.9531 in.) 75.010 - 75.020 mm (2.9531 - 2.9535 in.)
WD1-430	A Red or Yel B Blue or Grn	83.925 - 83.935 mm (3.3041 - 3.3045 in.) 83.935 - 83.945 mm (3.3045 - 3.3049 in.)	84.000 - 84.011 mm (3.3071 - 3.3075 in.) 84.011 - 84.022 mm (3.3075 - 3.3079 in.)
WD1-660, WD1- 670	A Red or Yel B Blue or Grn	94.920 - 94.930 mm (3.7370 - 3.7374 in.) 94.930 - 94.940 mm (3.7374 - 3.7378 in.)	95.000 - 95.011 mm (3.7402 - 3.7406 in.) 95.011 - 95.022 mm (3.7406 - 3.7410 in.)
WD1-750	A Red or Yel B Blue or Grn	99.890 - 99.900 mm (3.9326 - 3.9330 in.) 99.900 - 99.910 mm (3.9330 - 3.9335 in.)	100.000 - 100.011 mm (3.9370 - 3.9374 in.) 100.011 - 100.022 mm (3.9374 - 3.9379 in.)

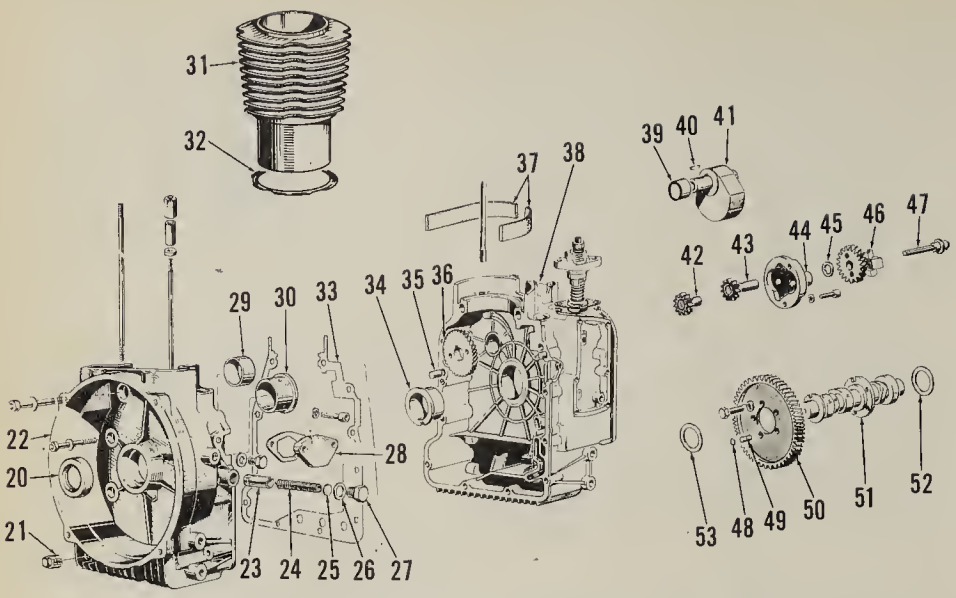
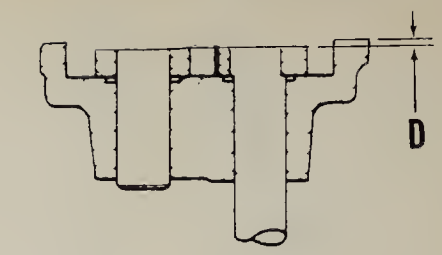


Fig. W1-11—Typical exploded view of crankcase. Balancer (41) is not used on Models WD1-340, WD1-350 and WD1-430.

20. Oil seal
21. Oil drain plug
22. Crankcase half
23. Oil pressure relief valve
24. Spring
25. Shim
26. Washer
27. Plug
28. Cover
29. Camshaft bushing
30. Main bearing
31. Cylinder
32. Shim gasket
33. Gasket
34. Main bearing
35. Dowel
36. Balancer gear
37. Felt
38. Crankcase half
39. Bushing
40. Key
41. Balancer
42. Driven gear
43. Drive gear & shaft
44. Oil pump body
45. Thrust washer
46. Balancer assy.
47. Push rod
48. Snap ring
49. Pin
50. Camshaft gear
51. Camshaft
52. Shims
53. Thrust washer



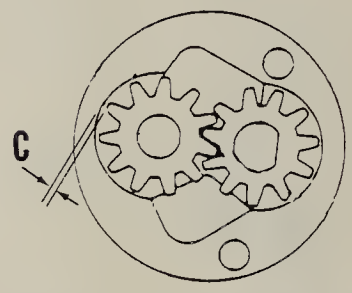


Fig. W1-13—Maximum oil pump gear side clearance (C) is 0.15 mm (0.006 inch) and maximum gear depth (D) is 0.10 mm (0.004 inch).

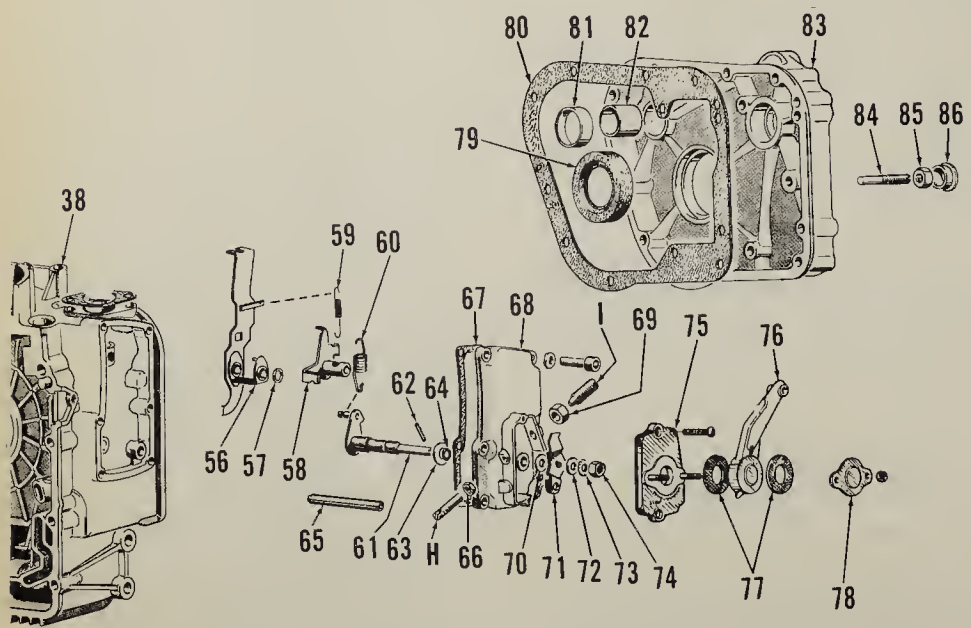


Fig. W1-12—Exploded view of governor linkage.

38. Crankcase half
56. Lever
57. Spacer
58. Pivot
59. Spring
60. Governor spring
61. Control shaft
62. Pin
63. Washer
64. "O" ring
65. Pivot shaft
66. Locknut
67. Gasket
68. Side cover
69. Locknut
70. Washer
71. Lever
72. Washer
73. Lockwasher
74. Nut
75. Cover
76. Control lever
77. Friction discs
78. Retainer
79. Seal
80. Gasket
81. Balancer bushing
82. Camshaft bushing
83. Gear cover
84. Max. fuel delivery screw
85. Nut
86. Plug

inch). Piston pin clearance in piston bore should be 0.002-0.011 mm (0.0001-0.0004 inch) with a wear limit of 0.06 mm (0.0024 inch).

When reinstalling piston rings, top compression ring and bottom oil control ring can be installed with either side up. On WD1-350, WD1-360 and WD1-430, center ring must be installed with side marked "TOP" facing upward. On WD1-660, WD1-670 and WD1-750, center ring must be installed with notched side facing downward. Position ring end gaps 120° apart.

Reverse disassembly procedure for reassembly. Arrow (A–Fig. W1-10) on piston crown must point towards flywheel end of engine. With piston at top dead center, clearance between piston crown and top edge of cylinder should be 0.8-0.9 mm (0.032-0.035 inch). Install cylinder shim gaskets (32–Fig. W1-11) as required to obtain desired clearance.

GOVERNOR

REMOVE AND REINSTALL. Refer to Fig. W1-12 for an exploded view of governor linkage. To remove or inspect governor linkage, unbolt side cover (68), rotate cover 90° clockwise to disengage governor spring (60) and remove side cover assembly. Remove gear cover (83) if easier access to governor is desired. Pull shaft (65) from crankcase to remove lever (56) and pivot (58), being careful not to drop spacer (57) into crankcase. Do not lose spacer (57), which must be installed in original position. Refer to OIL PUMP section if flyweight assembly (46–Fig. W1-11) must be removed.

Two different governor springs (60–Fig.W1-12) are used. Maximum governed speed is limited to 2200 rpm or 3000 rpm, depending on governor spring used. Long end of pivot spring (59) is connected to pivot (58).

Maximum fuel delivery screw (84) is located in gear cover (83) and should be adjusted to provide acceptable power without excessive smoke. With engine warm and under no load, accelerate engine quickly. If smoke is excessive, turn screw (84) clockwise. If additional fuel is needed, turn screw counterclockwise.

Carefully turn screw in ⅛ turn or less increments.

OIL PUMP

R&R AND OVERHAUL. Refer to GOVERNOR section and remove governor and control linkage. Remove gear cover if not previously detached. Unbolt and remove oil pump and governor assembly. Press gear and governor assembly (46–Fig. W1-11) off oil pump gear shaft (43). Inspect oil pump gears and housing and renew if damaged or worn excessively. Maximum gear backlash is 0.30 mm (0.012 inch). Maximum gear depth (D–Fig. W1-13) is 0.10 mm (0.004 inch). Maximum radial clearance (C) between side of gear and housing is 0.15 mm (0.006 inch). Reverse disassembly procedure to assemble oil pump. Be sure thrust washer (45–Fig. W1-11) is on oil pump shaft before pressing governor assembly onto shaft.

The oil pressure relief valve (23–Fig. W1-11) is located in side of crankcase. Oil pressure is adjusted by removing or adding shims (25). Maximum oil pressure should be 380 kPa (55 psi) for WD1-340, WD1-350 and WD1-430 engines, or 275 kPa (40 psi) for WD1-660, WD1-670 and WD1-750 engines.

CONNECTING ROD

R&R AND OVERHAUL. To remove connecting rod, drain engine oil and detach flywheel. Remove piston and cylinder as previously outlined. Unscrew crankcase screws (eleven screws on Models WD1-340, WD1-350 and WD1-430; twelve screws on all other models) and position crankcase with gear cover (83–Fig. W1-12) down. Lift off flywheel side crankcase half (22–Fig. W1-11) and remove connecting rod.

Inspect connecting rod and crankpin. If crankshaft must be removed, refer to CRANKSHAFT AND CRANKCASE section.

Crankpin diameter should be 48.221-48.237 mm (1.8985-1.8991 inches) on Models WD-340, WD1-350 and WD1-430, or 59.981-60.000 mm (2.3615-2.3622 inches) on all other models. Rod bearing clearance on Models WD1-340, WD1-350 and WD1-430 should be 0.030-0.072 mm (0.0012-0.0028 inch) with a maximum clearance of 0.10 mm (0.004 inch). Rod bearing clearance on Models WD1-660, WD1-670 and WD1-750 should be 0.040-0.10 mm (0.0016-0.0040 inch) with a maximum clearance of 0.12 mm (0.005 inch). Rod bearings are available in standard and 0.25 and 0.50 mm (0.010 and 0.020 inch) undersizes.

The small end rod bushing is renewable; refer to PISTON, PIN, RINGS AND CYLINDER section.

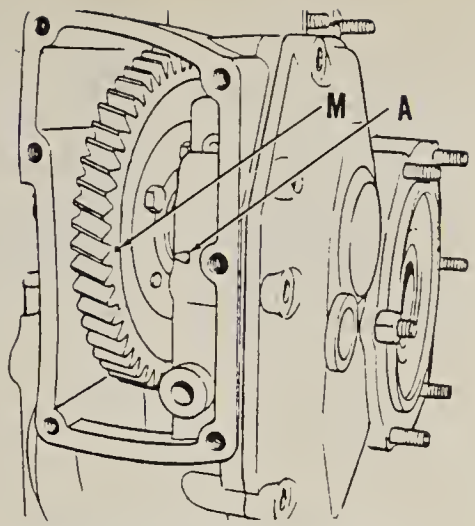


Fig. W1-14—View of camshaft gear timing mark (M) and crankcase mark (A) on Models WD1-340, WD1-350 and WD1-430.

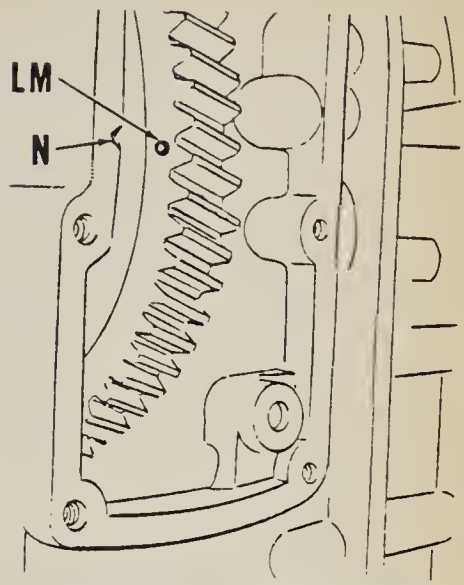


Fig. W1-15—View of large camshaft gear timing mark (LM) and crankcase notch (N) on Models WD1-660, WD1-670 and WD1-750.

Reverse removal procedure to install connecting rod. Tighten rod nuts to 34 N·m (25 ft.-lbs.) on Models WD1-340, WD1-350 and WD1-430, or 49 N·m (36 ft.-lbs.) on all other models. Be sure thrust washer (53–Fig. W1-11) is on camshaft end. Tighten eleven crankcase screws on Models WD1-340, WD1-350 and WD1-430 to 30 N·m (22 ft.-lbs.). On Models WD1-660, WD1-670 and WD1-750, tighten ten M8 crankcase screws to 30 N·m (22 ft.-lbs.) and two M12 crankcase screws to 69 N·m (51 ft.-lbs.)

CRANKSHAFT AND CRANKCASE

R&R AND OVERHAUL. To remove crankshaft, drain engine oil and detach flywheel. Unbolt side cover (68–Fig. W1-12), rotate cover 90° clockwise to disengage governor spring (60) and remove side cover assembly. Remove fuel injection pump, piston and cylinder as previously outlined. Remove cover (28–Fig. W1-11) or transfer fuel pump, if so equipped. Unscrew crankcase screws (eleven screws on Models WD1-340, WD1-350 and WD1-430; twelve screws on all other models) and position crankcase with gear cover (83–Fig. W1-12) down. Lift off flywheel side crankcase half (22–Fig. W1-11). Withdraw crankshaft and rod assembly, then remove rod if desired.

Crankshaft main bearing journal diameter should be 45.984-46.000 mm (1.8104-1.8110 inches) on Models WD1-340, WD1-350 and WD1-430, or 55.981-56.000 mm (2.2040-2.2047 inches) on all other models. Main bearing clearance should be 0.054-0.095 mm (0.002-0.004 inch) on Models WD1-340, WD1-350 and WD1-430. Main bearing clearance on Models WD1-660, WD1-670 and WD1-750 should be 0.04-0.08 mm (0.0016-0.0031 inch). Maximum main bearing clearance for all models is 0.12 mm (0.0047 inch). Main bearings (30 and 34–Fig. W1-11) are available in standard and 0.25 and 0.50 mm (0.010 and 0.020 inch) undersizes. If main bearings must be renewed, remove any components in crankcase which may be damaged by heat. Heat crankcase to 150°C (300°F), then using a suitable press, remove and install main bearings.

If camshaft bushing (29) must be renewed, heat crankcase half (22) to 150°C (300°F) prior to removal and installation.

If removed, install connecting rod on crankshaft and tighten rod nuts to 34 N·m (25 ft.-lbs.) on Models WD1-340, WD1-350 and WD1-430, or 49 N·m (36 ft.-lbs.) on all other models.

To install crankshaft on Models WD1-340, WD1-350 and WD1-430, rotate camshaft so timing mark (M–Fig. W1-14) on camshaft gear is aligned with arrow (A) on crankcase. Insert crankshaft into top crankcase half (38–Fig. W1-11) so crankpin is at top dead center. Recheck camshaft gear timing mark. With crankpin at top dead center, timing marks (M and A–Fig. W1-14) should be aligned.

To install crankshaft on Models WD1-660, WD1-670 and WD1-750, rotate camshaft so large timing mark (LM–Fig. W1-15) is aligned with notch (N) in crankcase. Insert crankshaft into pto crankcase half (38–Fig. W1-11) so red

paint mark (P–Fig. W1-16) is aligned with small camshaft gear timing mark (SM). Rotate crankshaft until red paint mark (P–Fig. W1-17) on crankshaft gear is adjacent to balancer gear. Red paint mark (P) must align with balancer gear mark (M). If marks (P and M) do not align, hold camshaft gear in place, withdraw crankshaft, rotate balancer so marks (P and M) will be aligned then reinsert crankshaft into crankcase. When properly mated, balancer gear mark (M) and red paint mark (P) will align on each crankshaft rotation, and red paint mark (P–Fig. W1-16) will align with small camshaft timing mark (SM) when large camshaft timing mark (LM–Fig. W1-15) is aligned with crankcase notch (N).

On all models, install rubber ring (11–Fig. W1-9) and oil seal (20–Fig. W1-11) with seal lip inward. Be sure thrust washer (53) is on camshaft end. Install crankcase half (22) but do not apply sealant to gasket or crankcase. Tighten eleven crankcase screws on Models WD1-340, WD1-350 and WD1-430 to 30 N·m (22 ft.-lbs.). On Models WD1-660, WD1-670 and WD1-750, tighten ten M8 crankcase screws to 30 N·m (22 ft.-lbs.) and two M12 crankcase screws to 69 N·m (51 ft.-lbs.)

Crankshaft end play should be 0.10-0.35 mm (0.004-0.014 inch) on Models WD1-340, WD1-350 and WD1-430, or 0.20-0.40 mm (0.008-0.016 inch) on all other models. If end play is excessive, remove crankshaft and install thicker thrust washer (14–Fig. W1-9).

Complete remainder of assembly by reversing disassembly procedure.

CAMSHAFT

R&R AND OVERHAUL. To remove camshaft, refer to previous section and disassemble crankcase but do not remove crankshaft. Remove gear cover (83–Fig. W1-12) and governor linkage. Set aside camshaft shims (52–Fig. W1-11) for future use. Detach gear (50) from camshaft (51) and withdraw camshaft from crankcase. Remove gear through side cover opening.

The camshaft is supported by bushings in the crankcase and gear cover. Maximum allowable camshaft journal clearance is 0.15 mm (0.006 inch). If the crankcase bushing (29–Fig. W1-11) requires renewal, refer to following section, as crankcase must be disassembled and heated for bushing installation. To renew bushing (81–Fig. W1-12), heat gear cover (83) to 150°C (300°F) before removal or installation. Be sure crankshaft seal (79) is not damaged by heat. Camshaft bushings are available in standard size and 0.25 and 0.50 mm (0.010 and 0.020 inch) undersizes.

Intake and exhaust cam lobe heights should be 32.775-33.025 mm (1.2904-1.3002 inches) on Models WD1-340, WD1-350 and WD1-430. Intake cam lobe height on Models WD1-660, WD1-670 and WD1-750 should be 39.966-40.216 mm (1.5735-1.5833 inches) and exhaust cam lobe height should be 39.880-40.130 mm (1.5701-1.5799 inches). Fuel injection cam lobe height should be 34.925-35.075 mm (1.3750-1.3809 inches) on Models WD1-340, WD1-350 and WD1-430 or 40.857-41.107 mm (1.6085-1.6184 inches) on all other models.

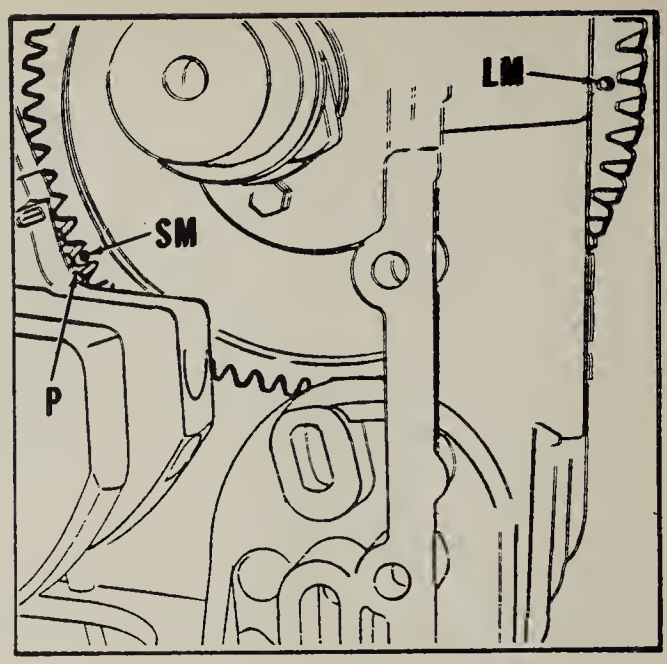


Fig. W1-16—View of large (LM) and small (SM) camshaft timing marks and red paint mark (P) on crankshaft gear of Models WD1-660, WD1-670 and WD1-750.

To install camshaft, insert gear (50–Fig. W1-11) into crankcase through side cover opening and mate gear with crankshaft gear. On Models WD1-340, WD1-350 and WD1-430 with crankpin at top dead center, camshaft timing gear mark (M–Fig. W1-14) must be aligned with arrow (A) on crankcase. On Models WD1-660, WD1-670 and WD1-750, red paint mark (P–Fig. W1-16) on crankshaft gear must align with small camshaft gear timing mark (SM) while large camshaft gear timing mark (LM–Fig. W1-15) must align with crankcase notch (N). While holding camshaft gear in mesh with crankshaft gear, insert camshaft into crankcase and through camshaft gear. Rotate camshaft so locating pin (49–Fig. W1-11) in gear enters notch in camshaft flange. Install camshaft gear screws. Place original shims (52) on camshaft and install governor linkage and gear cover. Tighten gear cover screws to 25 N·m (18 ft.-lbs.). Complete remainder of assembly by reversing disassembly procedure, but do not install side cover.

Check camshaft end play, which should be 0.10-0.30 mm (0.004-0.012 inch) on Models WD1-340, WD1-350 and WD1-430 or 0.20-0.40 mm (0.008-0.016 inch) on all other models. Install or remove shims (52) as needed to obtain desired end play. Attach governor spring (60–Fig. W1-12) and install side cover.

BALANCER

Models WD1-660, WD1-670 And WD1-750

REMOVE AND REINSTALL. Models WD1-660, WD1-670 and WD1-750

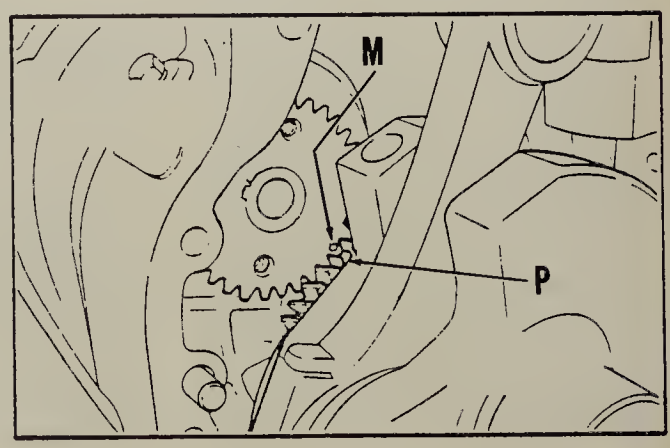
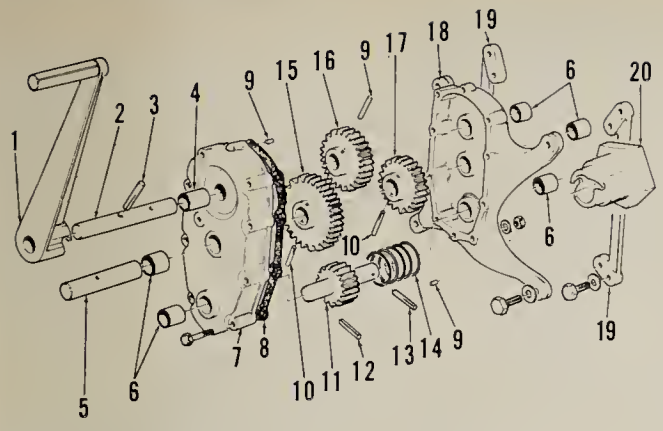


Fig. W1-17—Balancer gear mark (M) and red paint mark (P) on crankshaft gear should be aligned on Models WD1-660, WD1-670 and WD1-750.



1. Crank
2. Shaft
3. Pin
4. Bushing
5. Shaft
6. Bushings

Fig. W1-18—Exploded view of crank type manual starter used on some models. Adapter (19) is used on Models WD1-660, WD1-670 and WD1-750.

7. Housing half
8. Gasket
9. Dowel
10. Pin
11. Output gear & shaft
12. Pin
13. Pin
14. Spring
15. Gear (29 teeth)
16. Gear (23 teeth)
17. Gear (21 teeth)
18. Housing half
19. Adapter
20. Crank jaw

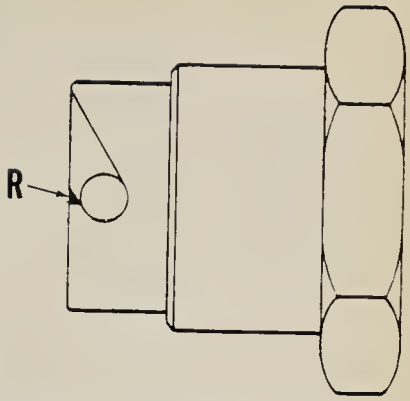


Fig. W1-19—File away area (R) on crank jaw to dimensions shown for easier disengagement.

are equipped with a balancer (41–Fig. W1-11) which is driven by gear (36) which meshes with the crankshaft gear.

To remove balancer, remove crankshaft as previously outlined then remove gear cover being careful not to lose camshaft shims (52). Use a suitable puller to remove gear (36) from balancer shaft.

Inspect balancer, gear and bushings (39–Fig. W1-11 and 82–Fig. W1-12). Renew if damaged or excessively worn. Crankcase or gear cover must be heated to 150°C (300°F) when removing or installing bushings. Remove any components which may be damaged by heat.

To install balancer, insert balancer into crankcase then use a suitable press to install gear (36–Fig. W1-11) onto balancer shaft with timing gear mark (M–Fig. W1-17) out. Install gear cover being sure to install camshaft shims (52–Fig. W1-11). Refer to CRANKSHAFT AND CRANKCASE section for crankshaft installation and reassembly.

MANUAL STARTER

R&R AND OVERHAUL. Refer to Fig. W1-18 for an exploded view of crank type manual starter used on some models. Unscrew housing mounting screws to remove starter from engine. Unscrew housing screws and separate housing halves (7 and 18) for access to starter components.

Inspect starter components for damage and excessive wear. Heat housing halves to 150°C (300°F) before removing and installing bushings. Manufacturer recommends renewing both bushings for a particular shaft.

When assembling starter, adequately grease all internal components. Be sure starter operates properly after assembly without binding or sticking. Manufacturer recommends filing down area (R–Fig. W1-19) of crank jaw so starter pin disengages easier. With starter mounted on engine, starter pin (13–Fig. W1-18) must be at least 1.5 mm (1/16 inch)

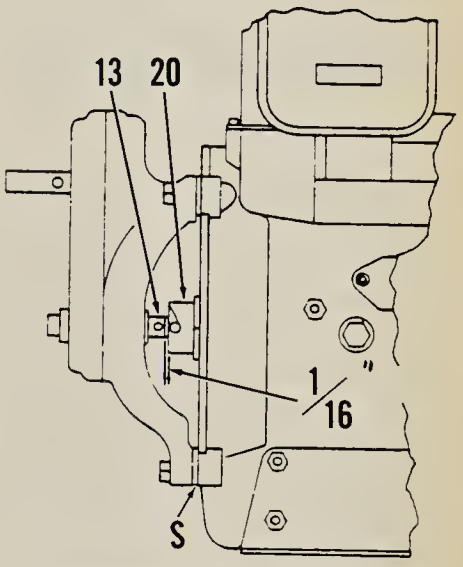


Fig. W1-20—Output shaft pin (13) must be at least 1.5 mm (1/16 inch) from crank jaw (20) when disengaged. Install shims (S) between starter housing and engine to obtain clearance.

from crank jaw as shown in Fig. W1-20. Install shims (S) between starter and engine to obtain desired clearance.

WISCONSIN

Model	No. Cyls.	Bore	Stroke	Displ.
WD2-860	2	84 mm (3.307 in.)	78 mm (3.071 in.)	864 cc (52.7 cu. in.)
WD2-1000	2	86 mm (3.386 in.)	86 mm (3.386 in.)	1000 cc (61.0 cu. in.)

Engines covered in this section are air-cooled, two-cylinder, four-stroke diesel engines. Crankshaft rotation is counterclockwise at pto end. Number 1 cylinder is nearer pto end of engine.
Metric fasteners are used throughout engine.

MAINTENANCE

LUBRICATION

Recommended engine oil is SAE 10W or 5W-20 when temperatures are below minus 18°C (0°F), SAE 10W or 10W-30 for temperatures between minus 18°C (0°F) and 0°C (32°F), SAE 20 or 15W-40 for temperatures between 0°C (32°F) and 20°C (68°F) and SAE 40 or 15W-40 for temperatures above 20°C (68°F). API oil classification should be CD. Manufacturer recommends renewing oil after every 100 hours of operation. Oil should be drained while engine is hot.

An external oil filter (F – Fig. W2-1) is located on side of engine. Manufacturer recommends renewing filter after every other oil change. A reusable filter element is located on the oil pickup tube (P – Fig. W2-2). Filter should be removed and cleaned after every 200 hours of operation. Renew filter if damaged or if unable to get filter completely clean.

Oil pressure with engine warm and running at full speed should be 275 kPa (40 psi). An oil pressure gage may be connected after unscrewing test port plug (T – Fig. W2-1). Refer to OIL PUMP section to adjust pressure relief valve setting.

ENGINE SPEED ADJUSTMENT

Idle speed is adjusted by turning idle speed screw (I – Fig. W2-3) and high speed is adjusted by turning high speed screw (H). Idle speed should be 1500-1800 rpm while maximum governed speed under load is 3000 rpm.

FUEL SYSTEM

FUEL FILTERS. A fuel filter is located in the fuel tank and an external fuel filter is mounted on side of engine. Renew fuel filters after every 200 hours of operation or sooner if required.

BLEED FUEL SYSTEM. On gravity-feed fuel systems, a fuel return line and check valve are connected to the fuel injection pump as well as the fuel supply line. Fuel supply line should bleed air automatically up to fuel injection pump on gravity flow systems. To bleed high pressure injection lines, loosen fittings for high pressure lines at injectors then rotate engine crankshaft to operate fuel injection pump until air-free fuel flows from injection lines. Retighten injection lines.

On engines equipped with a fuel transfer pump, loosen fuel supply line fitting on injection pump then rotate engine crankshaft to operate fuel transfer pump until air-free fuel flows from fuel line. Retighten fuel supply line and loosen fittings for high pressure injection lines at injectors. Rotate engine crankshaft to operate fuel injection pump until air-free fuel flows from injection lines. Retighten injection lines.

INJECTION PUMP TIMING

Injection pump timing is adjusted using shim gaskets (29 – Fig. W2-4) between pump body and mounting surface on crankcase. Refer to INJECTION PUMP section for pump removal and installation.

To check injection pump timing, unscrew high pressure injection line of

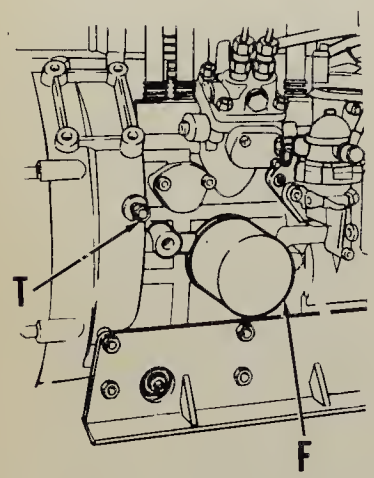


Fig. W2-1—View showing location of external oil filter (F). Unscrew plug (T) and connect a pressure gage to measure oil pressure.

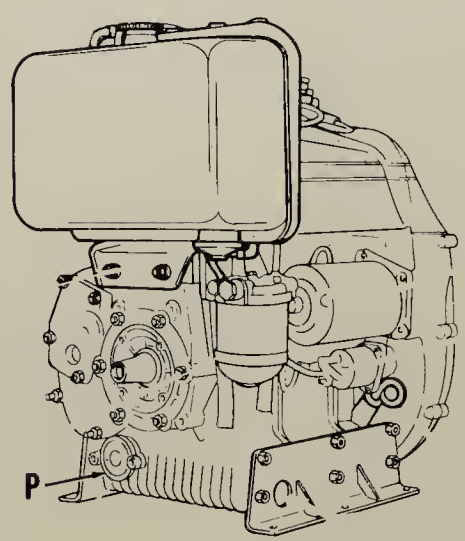


Fig. W2-2—Remove oil pickup (P) for access to internal oil filter.

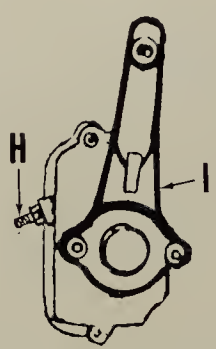


Fig. W2-3—View showing location of high speed adjusting screw (H). Idle speed screw is located behind speed control lever at (I).

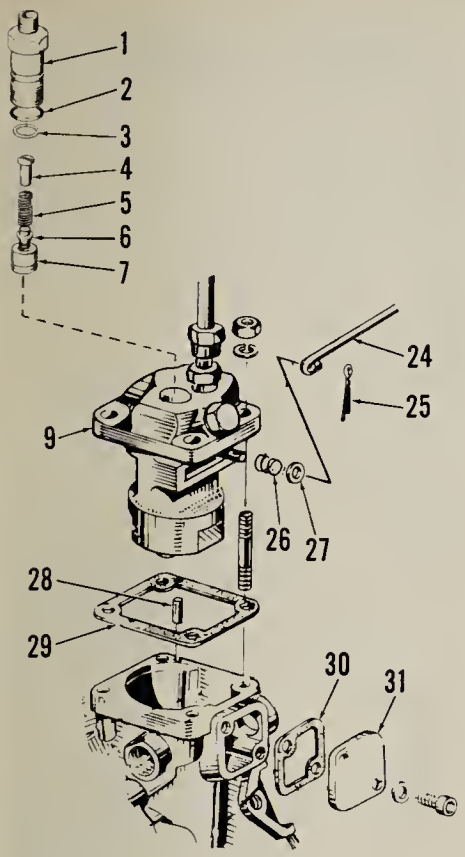


Fig. W2-4—Partial exploded view of fuel injection pump.

1. Delivery valve holder
2. "O" ring
3. Gasket
4. Spring guide
5. Spring
6. Delivery valve
7. Delivery valve seat
9. Fuel injection pump
24. Control rod
25. Cotter pin
26. Spring
27. Washer
28. Pin
29. Shim gasket
30. Gasket
31. Cover

number 1 cylinder from injection pump delivery valve holder (1). Unscrew delivery valve holder (1) and remove spring (5), spring guide (4) and delivery valve (6), then screw delivery valve holder (1) back into pump. Move throttle control to full speed position. Rotate engine in normal direction (counterclockwise at pto) so number 1 piston is on compression stroke – it may be necessary to connect a gravity-flow fuel tank to fuel injection pump if not so equipped. Note fuel will flow out of delivery valve holder. Stop engine rotation at moment fuel ceases to flow. Timing mark (R – Fig. W2-5) should be within 3 mm (1/8 inch) of injection timing mark (N) on crankcase. To advance injection timing, remove shim gaskets (29 – Fig. W2-4); install shim gaskets to retard injection timing. Reinstall removed pump parts after checking timing.

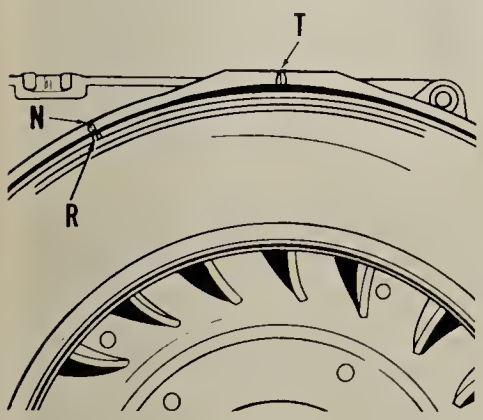


Fig. W2-5—Number 1 cylinder fuel injection should occur when flywheel reference mark (R) is aligned with crankcase mark (N). Number 1 piston is at top dead center when flywheel reference mark (R) is aligned with crankcase mark (T).

REPAIRS

TIGHTENING TORQUES

Refer to the following table for special tightening torques. All fasteners are metric.

Connecting rod	34 N·m (25 ft.-lbs.)
Crankcase	See text
Cylinder head	44 N·m (33 ft.-lbs.)
Fan	34 N·m (25 ft.-lbs.)
Flywheel	176 N·m (130 ft.-lbs.)
Gear cover	25 N·m (18 ft.-lbs.)
Injection pump	25 N·m (18 ft.-lbs.)
Injector retainer plate	10 N·m (7 ft.-lbs.)
Main bearing center support	See text

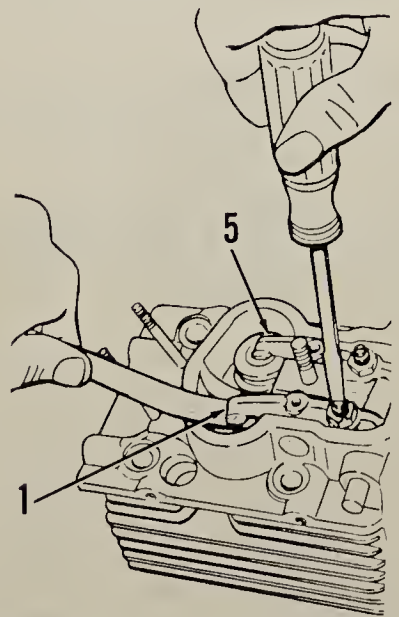


Fig. W2-6—Valve clearance should be 0.15 mm (0.006 inch) at exhaust rocker arm (1) and 0.10 mm (0.004 inch) at intake rocker arm (5).

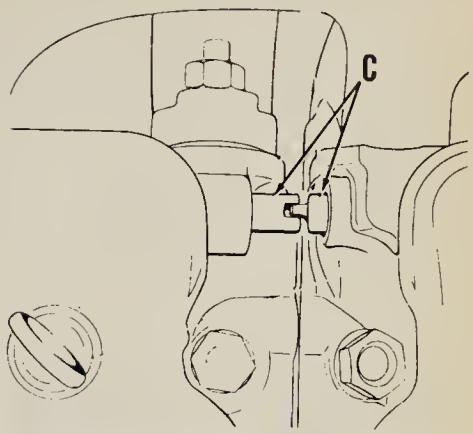


Fig. W2-7—Before removing cylinder head, rotate compression release shafts (C) so slot and tang in shaft ends are vertical.

VALVE ADJUSTMENT

Valve clearance may be adjusted after removing rocker arm cover and turning crankshaft to position piston for cylinder being adjusted at TDC on compression stroke. Turn rocker arm adjusting screw (Fig. W2-6) until appropriate size feeler gage can be inserted between rocker arm and valve stem end. Recommended clearance with engine cold is 0.15 mm (0.006 inch) for exhaust and 0.10 mm (0.004 inch) for intake.

CYLINDER HEAD AND VALVE SYSTEM

R&R AND OVERHAUL. To remove cylinder heads, disconnect high pressure and return fuel injection lines. Immediately cap fuel lines. Remove muffler, air cleaner, exhaust and intake manifolds. Turn compression release lever so connecting tang and slot on compression release shafts are vertical as shown in Fig. W2-7. Remove rocker arm covers, unscrew cylinder head retaining nuts and remove cylinder heads. Remove and discard rubber seals (R – Fig. W2-8) on cylinder head studs and upper push rod tube seals.

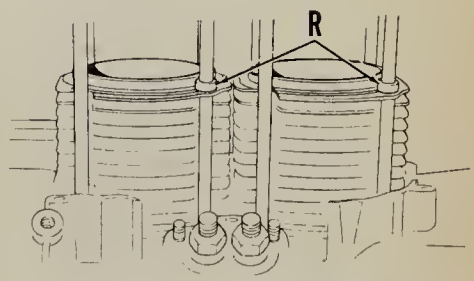


Fig. W2-8—View showing location of rubber seals (R) on cylinder head studs.

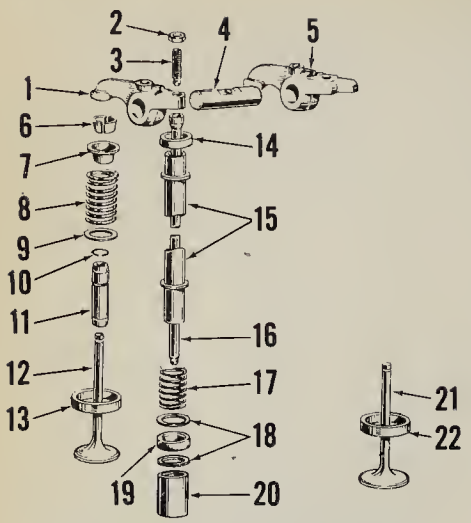


Fig. W2-9—Exploded view of valve train.

1. Exhaust rocker arm
2. Locknut
3. Adjuster
4. Rocker arm shaft
5. Intake rocker arm
6. Keys
7. Spring retainer
8. Valve spring
9. Washer
10. Snap ring
11. Valve guide
12. Exhaust valve
13. Exhaust valve seat
14. Seal
15. Push rod tube
16. Push rod
17. Spring
18. Washer
19. Seal
20. Cam follow
21. Intake valve
22. Intake valve seat

Valve face angle for both valves is 45½° and valve seat angle is 45°. Valve seats are renewable and must be installed with head heated to 200°C (392°F). There should be an interference fit of 0.079-0.120 mm (0.0031-0.0047 inch) between outside diameter of seat and bore in cylinder head. With valves installed, top of valve heads should be recessed 0.60-0.95 mm (0.024-0.037 inch) below surface of cylinder head.

Valve stem diameter is 6.945-6.960 mm (0.2734-0.2740 inch) for both valves and valve guide inside diameter is 7.000-7.015 mm (0.2756-0.2762 inch). Valve stem clearance should be 0.040-0.070 mm (0.0016-0.0028 inch) with a maximum allowable valve stem clearance of 0.2 mm (0.008 inch). Valve guides are renewable. To remove valve guide, press guide out top of cylinder head. To install valve guide, position locating ring (10—Fig. W2-9) on guide, then press guide into head from top side of head with ring end up. Press guide into head until locating ring is seated in head groove.

Reassemble by reversing disassembly procedure. Install new "O" rings on compression release shafts and install shafts so slot or tang on shaft end is towards inner side of cylinder head as shown in Fig. W2-7. Install new upper rubber seal on push rod tubes. Install new rubber seals on cylinder head studs shown in Fig. W2-8. Before tightening cylinder head nuts, install exhaust and intake manifolds to correctly position heads, then tighten cylinder head nuts to 44 N·m (33 ft.-lbs.).

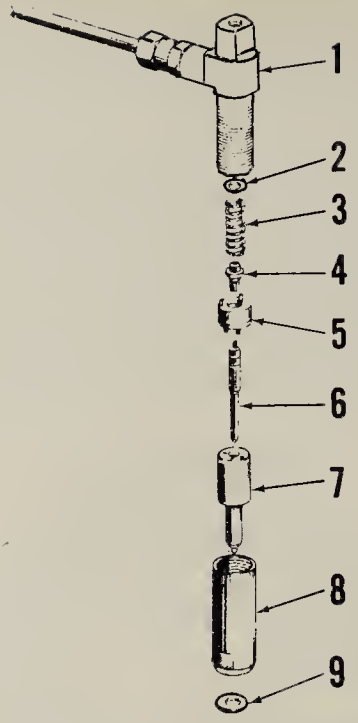


Fig. W2-10—Exploded view of injector.

1. Body
2. Shim
3. Spring
4. Push piece
5. Spacer
6. Valve
7. Nozzle
8. Nozzle holder
9. Gasket

INJECTOR

REMOVE AND REINSTALL. To remove injector, first clean dirt from injector, injection line, return line and cylinder head. Disconnect return line and high pressure injection line and immediately cap or plug all openings. Unscrew retainer plate and remove injector and copper washer.

Reverse removal procedure to reinstall injector. Install a new copper washer (9—Fig. W2-10). Tighten injector retaining plate nuts to 10 N·m (7 ft.-lbs.).

TESTING. A suitable test stand is required to check injector operation. Only clean, approved testing oil should be used to test injector.

WARNING: Fuel leaves the injection nozzle with sufficient force to penetrate the skin. When testing, keep yourself clear of nozzle spray.

Attach injector to tester and operate pump lever a few quick strokes to purge air from injector and to make sure nozzle valve is not stuck. When operating properly during test, injector nozzle will emit a buzzing sound and cut off quickly with no leakage at seat. Spray pattern should be uniform and well atomized.

Opening pressure should be 19600-20600 kPa (2845-2985 psi). Opening pressure is adjusted by varying the thickness of shims (2—Fig. W2-10).

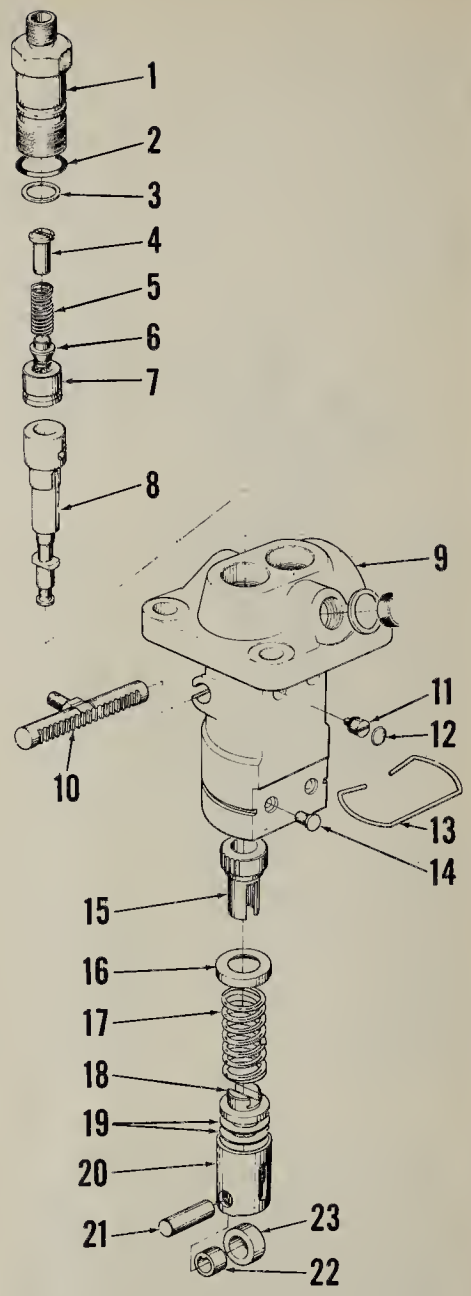


Fig. W2-11—Exploded view of fuel injection pump.

1. Delivery valve holder
2. "O" ring
3. Gasket
4. Spring guide
5. Spring
6. Delivery valve
7. Delivery valve seat
8. Plunger
9. Body
10. Control rack
11. Pin
12. Plug
13. Clip
14. Pin
15. Control sleeve
16. Spring seat
17. Spring
18. Spring seat
19. Shims
20. Tappet
21. Pin
22. Inner roller
23. Outer roller

Operate tester slowly to maintain pressure of 16200 kPa (2350 psi) and check for nozzle valve leakage. If a drop forms at nozzle tip within 10 seconds, nozzle valve is not seating and injector must be overhauled or renewed.

OVERHAUL. Clamp injector body (1—Fig. W2-10) in a vise with nozzle pointing upward. Unscrew nozzle holder nut (8), then remove injector components as shown in Fig. W2-10. Thor-

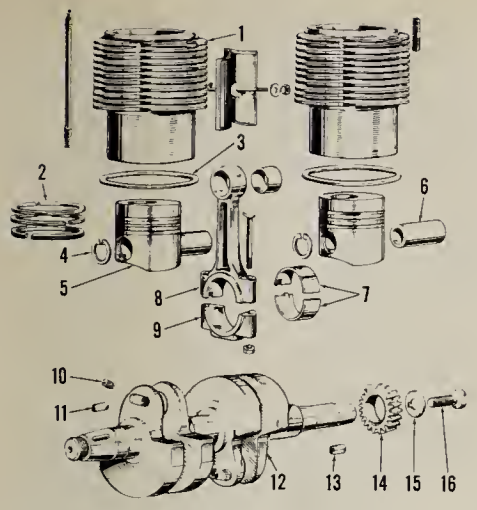


Fig. W2-12—Exploded view of crankshaft assembly.

1. Cylinder
2. Piston rings
3. Gasket
4. Snap ring
5. Piston
6. Piston pin
7. Rod bearing
8. Connecting rod
9. Rod cap
10. Plug
11. Key
12. Crankshaft
13. Key
14. Gear
15. Slotted washer
16. Cap screw

Table 1—Color codes and corresponding dimensions for standard pistons and cylinders

Model	Color Code	Piston O.D.	Cylinder I.D.
WD2-860	Red or Yellow	83.925-83.935mm (3.3041-3.3045in.)	84.000-84.011mm (3.3071-3.3075in.)
WO2-860	Blue or Green	83.935-83.945mm (3.045-3.3049in.)	84.011-84.022mm (3.3075-3.3079in.)
WD2-1000	Red or Yellow	85.920-85.930mm (3.3827-3.3831in.)	86.000-86.011mm (3.3858-3.3862in.)
WD2-1000	Blue or Green	85.930-85.940mm (3.3831-3.3835in.)	86.011-86.022mm (3.3863-3.3867in.)

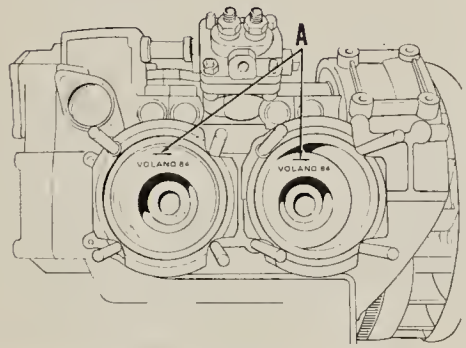


Fig. W2-13—Arrow (A) on piston crown must point towards flywheel.

oughly clean all parts in a suitable solvent. Clean inside orifice of nozzle tip with a wooden cleaning stick. When reassembling injector, make certain all components are clean and wet with clean diesel fuel oil. Tighten nozzle holder nut (8) to 49 N·m (36 ft.-lbs.).

INJECTION PUMP

R&R AND OVERHAUL. To remove fuel injection pump, disconnect fuel lines and remove cover (31 – Fig. W2-4) adjacent to pump. Place a clean rag underneath control rod (24) so cotter pin (25) cannot fall into crankcase. Then, remove cotter pin (25) and detach control rod end from pump control rack pin. Unscrew pump retaining nuts and remove fuel injection pump. Do not lose shim gaskets (29).

Refer to Fig. W2-11 for an exploded view of fuel injection pump. The injection pump should be tested and overhauled by a shop qualified in diesel fuel injection pump repair.

Reverse removal procedure for reinstallation. Tighten pump retaining nuts to 25 N·m (18 ft.-lbs.). If pump is renewed or overhauled, or original shim gaskets are not used, refer to INJECTION PUMP TIMING section and adjust pump timing.

PISTON, PIN, RINGS AND CYLINDER

R&R AND OVERHAUL. Remove cylinder head as previously outlined. If piston and cylinder do not require service but only removal, proceed as follows: Rotate crankshaft so piston to be removed is at top dead center. Lift cylinder up until piston pin is exposed, remove piston pin retainer, withdraw piston pin and remove cylinder and piston as a unit. If piston, rings or cylinder requires service, lift cylinder off crankcase, remove piston pin retainer, withdraw piston pin and remove piston.

Standard size pistons and cylinders are color-coded red, yellow, blue or green. A paint dot is located on inside of piston and on outside of cylinder. Piston diameter is measured 12 mm (1/2 inch) from bottom of piston skirt on Model WD2-860 or 15 mm (19/32 inch) from bottom of piston skirt on Model WD2-1000. Refer to Table 1 for piston and corresponding cylinder dimensions.

Check cylinder bore for excessive wear or other damage. Cylinders may be rebored for installation of 0.5 mm (0.020 inch) or 1.0 mm (0.040 inch) oversize pistons and rings. Clearance between piston skirt and cylinder bore should be 0.066-0.086 mm (0.0026-0.0034 inch) for WD2-860 and 0.071-0.091 mm (0.0028-0.0036 inch) for WD2-1000.

The top compression ring is a keystone type and second compression ring is rectangular. Piston ring end gap should be 0.30-0.45 mm (0.012-0.018 inch). Side clearance for second compression ring in piston groove should be 0.050-0.082 mm (0.002-0.003 inch) for WD2-860 and 0.070-0.102 mm (0.003-

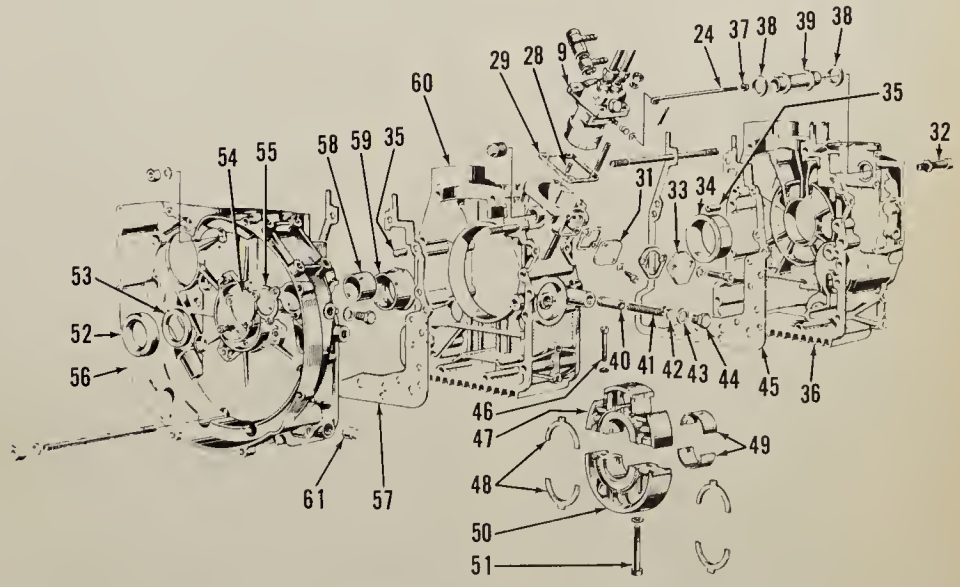


Fig. W2-14—Exploded view of crankcase assembly.

9. Fuel injection pump
24. Control rod
28. Pin
29. Shim gasket
31. Cover
32. Socket head screw
33. Cover
34. Main bearing
35. Pin
36. Pto crankcase section
37. Nut
38. Seal
39. Tube
40. Oil pressure relief valve
41. Spring
42. Shim
43. Washer
44. Plug
45. Gasket
46. Screw
47. Upper main bearing support half
48. Thrust washers
49. Main bearing
50. Lower main bearing support half
51. Screw
52. Inner seal ring
53. Oil seal
54. Cover
55. Gasket
56. Flywheel crankcase section
57. Gasket
58. Camshaft bushing
59. Main bearing
60. Center crankcase sectior
61. Oil drain plug

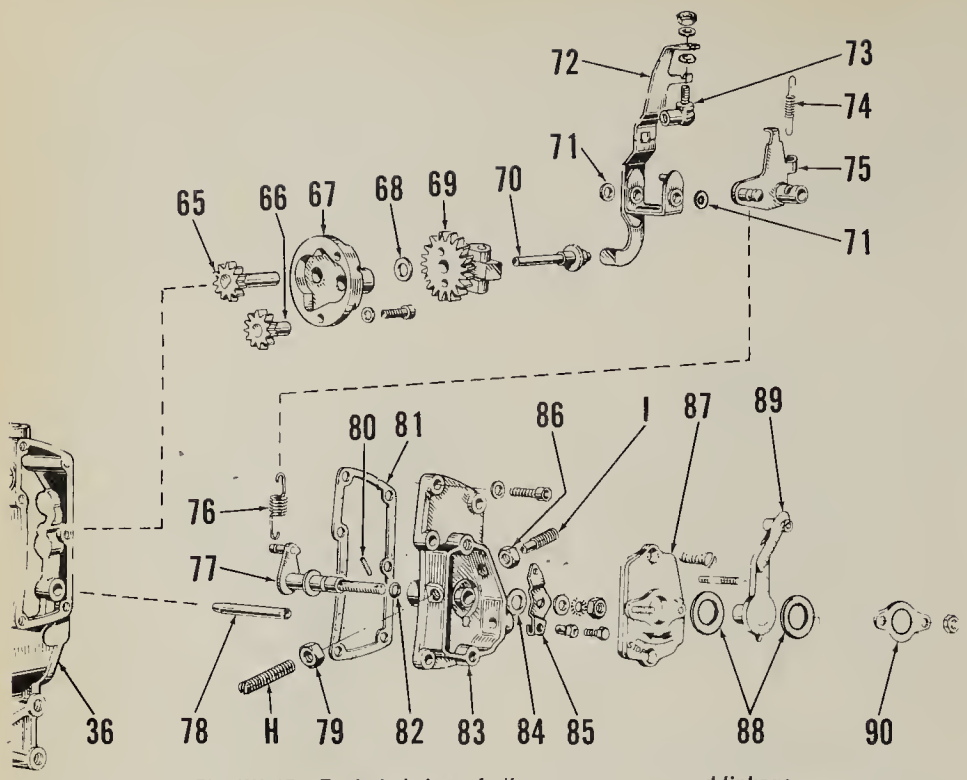


Fig. W2-15—Exploded view of oil pump, governor and linkage.

H. High speed screw
I. Idle speed screw
36. Pto crankcase section
65. Drive gear
66. Driven gear
67. Oil pump body
68. Thrust washer
69. Governor assy.
70. Push rod
71. Shims
72. Governor arm
73. Control rod end
74. Spring
75. Pivot
76. Spring
77. Lever & shaft
78. Shaft
79. Locknut
80. Pin
81. Gasket
82. "O" ring
83. Side cover
84. Washer
85. Lever
86. Locknut
87. Cover
88. Washers
89. Speed control lever
90. Plate

0.004 inch) for WD2-1000. Oil control ring side clearance should be 0.040-0.072 mm (0.0016-0.0028 inch) for all engines. Maximum allowable side clearance for either ring on all engines is 0.25 mm (0.010 inch).

When reinstalling piston rings, center ring must be installed with side marked "TOP" facing upward. Top ring and oil control ring can be installed with either side up. Stagger ring end gaps 120° apart.

Reverse disassembly procedure for reassembly. Arrow (A – Fig. W2-13) on piston crown must point towards flywheel end of engine. With piston at top dead center, clearance between piston crown and top edge of cylinder should be 0.8-0.9 mm (0.032-0.035 inch). Install cylinder shim gaskets (3 – Fig. W2-12) required to obtain desired clearance.

GOVERNOR

REMOVE AND REINSTALL. Refer to Fig.W2-15 for an exploded view of governor and control linkage. Remove cover (83) and gear cover (98 – Fig. W2-18) for access to governor and linkage. Do not lose camshaft shims (95), which may remain on gear cover. Mark shims (71 – Fig. W2-15) so they may be returned to original position.

Governor gear (69) is pressed on oil pump drive gear shaft (65), so oil pump and governor unit must be removed to press governor gear off shaft. Governor gear and flyweights (69) are available only as a unit assembly. Install thrust washer (68) on shaft before pressing governor gear assembly onto shaft.

Distance (D – Fig. W2-17) between speed control rod ends should be 129 mm (5 inches). Remove cover (31 – Fig. W2-14) and place a rag underneath control rod so cotter pin cannot fall into crankcase. Detach cotter pin securing rod end and withdraw control rod (24). Adjust length of control rod by turning rod end (73 – Fig. W2-17).

Reassemble by reversing removal procedure. Install shims (71 – Fig. W2-15) in their original location. Install spring (74) so long end is connected to intermediate lever (75) as shown in Fig. W2-16. Tighten gear cover nuts to 25 N·m (18 ft.-lbs.).

Maximum fuel delivery screw (T-Fig. W2-18) is located in gear cover (98) and should be adjusted to provide acceptable power without excessive smoke. With engine warm and under no load, accelerate engine quickly. If smoke is excessive, turn screw (T) clockwise. If additional fuel is needed, turn screw counterclockwise. Carefully turn screw in 1/8 turn or less increments.

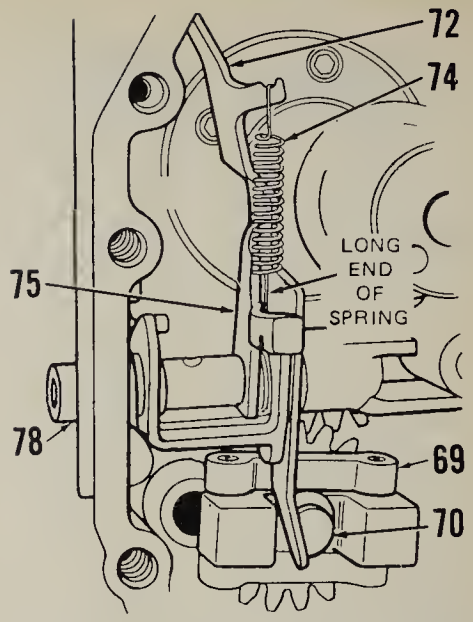


Fig. W2-16—View of governor linkage. Long end of spring (74) attaches to pivot (75).

OIL PUMP

R&R AND OVERHAUL. Refer to GOVERNOR section and remove governor and oil pump unit. Press governor off oil pump gear shaft (65 – Fig. W2-15). Inspect oil pump gears and housing and renew if damaged or worn excessively. Oil pump housing and gears are available individually. Reverse disassembly procedure to assemble oil pump. Be sure thrust washer (68) is on oil pump shaft before pressing governor assembly onto shaft.

The oil pressure relief valve (40 – Fig. W2-14) is located adjacent to oil filter. Oil pressure is adjusted by removing or installing shims (42). Refer to LUBRICATION section for oil pressure testing.

CAMSHAFT

R&R AND OVERHAUL. To remove camshaft, refer to previous sections and remove cylinder heads and fuel injection pump. Remove push rods and push rod tubes. Extract and mark cam followers so they can be returned to original bores. Refer to GOVERNOR section and remove governor linkage. Remove fuel transfer pump on models so equipped. Set aside shims (95 - Fig. W2-18) for future use. Detach gear (94) from camshaft (91), then rotate camshaft so

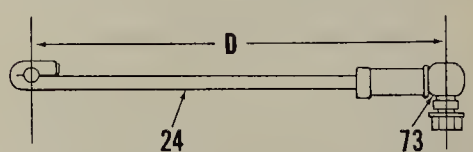


Fig. W2-17—Length (D) between control rod ends should be 129 mm (5 inches).

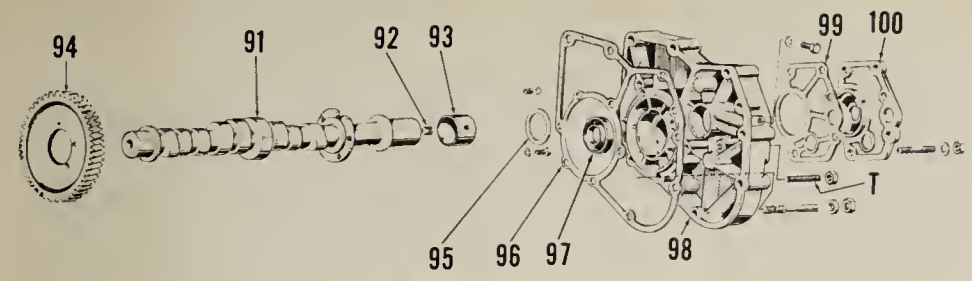


Fig. W2-18—Exploded view of camshaft.

91. Camshaft
92. Plug
93. Bushing
94. Gear
95. Shims
96. Gasket
97. Oil seal
98. Gear cover
99. Gasket
100. Cover

flat (F – Fig. W2-19) on camshaft flange coincides with crankcase projection (P). Carefully withdraw camshaft.

The camshaft is supported by bushings in the gear cover and crankcase. To inspect bushing (58 – Fig. W2-14) in the crankcase, remove flywheel and cover (54). If camshaft bushing (58) must be renewed, disassemble crankcase. Maximum allowable camshaft journal clearance is 0.2 mm (0.008 inch). Camshaft bushings are available in undersizes of 0.25 and 0.50 mm (0.010 and 0.020 inch).

To install camshaft, rotate crankshaft so number 1 piston is at top dead center. Insert camshaft gear (94 – Fig. W2-18) through control linkage opening in crankcase so dowel pin (101 – Fig. W2-20) side of gear is towards end of crankcase. Insert camshaft through camshaft gear into crankcase while noting flat (F – Fig. W2-19) on camshaft flange which must coincide with crankcase projection (P). Engage camshaft gear with crankshaft gear so camshaft gear timing mark (M – Fig. W2-20) is aligned with crankcase timing arrow (A). Hold camshaft gear then rotate camshaft so camshaft flange notch engages camshaft gear pin (101). Install camshaft screws and recheck timing marks. Place original shims (95 – Fig. W2-18) on camshaft and install governor linkage and gear cover. Tighten gear cover nuts to 25 N·m (18 ft.-lbs.). Check camshaft end play, which should be 0.15-0.25 mm (0.006-0.010 inch). Install or remove shims (95) as needed to obtain desired end play. Complete reassembly by reversing removal procedure.

CRANKSHAFT AND CRANKCASE

R&R AND OVERHAUL. Refer to Fig. W2-14 for an exploded view of crankcase, which is constructed in three sections: flywheel end, center and pto end.

To remove crankshaft, remove cylinders, pistons and camshaft as previously outlined. Remove electric starter, flywheel and alternator. Remove covers (33) at crankcase joints – there is only one cover if engine is equipped with a fuel transfer pump. Unscrew eleven retaining nuts from crankcase flywheel section and separate flywheel section from remainder of crankcase. Remove socket head screw (32 – Fig. W2-14 or W2-21) adjacent to camshaft bore. Separate center crankcase section with crankshaft from pto crankcase section. Remove control rod tube (39) and seals

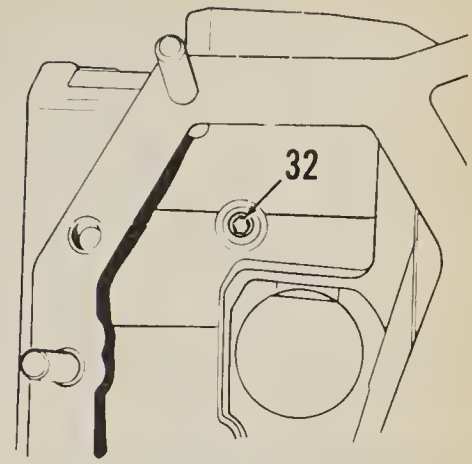


Fig. W2-21—View showing location of socket head screw (32) in pto crankcase section.

(38). Detach connecting rods. Unscrew two socket head screws (51) in bottom of center crankcase which secure main bearing support in crankcase. Press crankshaft and main bearing support out of center crankcase. Unscrew main bearing support screws (46) and separate support halves (47 and 50) from crankcase.

Crankcase main journal diameter should be 52.702-52.733 mm (2.0749-2.0761 inches) for center journal and 46.044-46.069 mm (1.8128-1.8137 inches) for end journals. Main bearing clearance should be 0.043-0.079 mm (0.0017-0.0031 inch) for center main bearing and 0.046-0.084 mm (0.0018-0.0033 inch) for end main bearings. Maximum allowable main bearing clearance is 0.2 mm (0.008 inch). Main bearings are available in undersizes of 0.25 and 0.50 mm (0.010 and 0.020 inch).

Crankpin diameter should be 48.267-48.294 mm (1.9003-1.9013 inches) and rod bearing clearance should be 0.030-

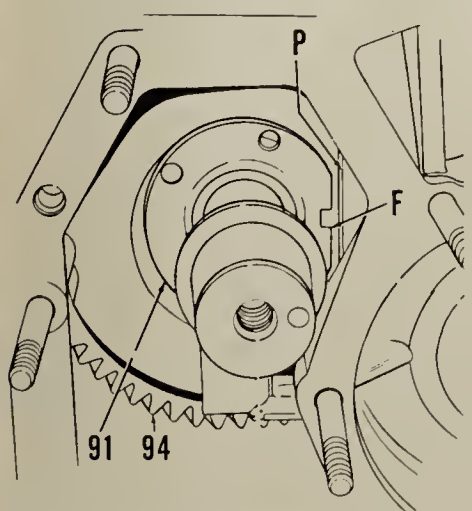


Fig. W2-19—Turn camshaft (91) so flat (F) on flange wall will pass crankcase projection (P).

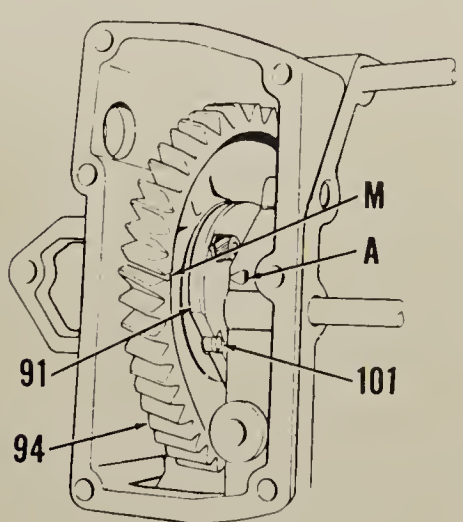


Fig. W2-20—Mate camshaft (91) with gear (94) as outlined in text.

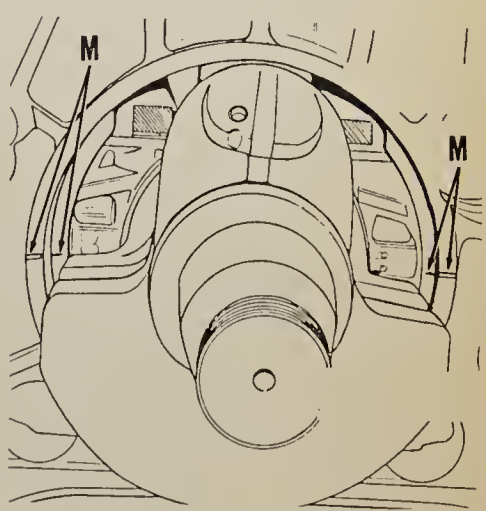


Fig. W2-22—Align crankshaft support and crankcase marks (M) as shown.

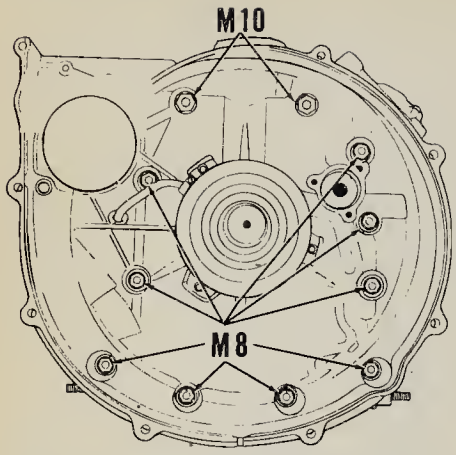


Fig. W2-23—View showing location of M8 and M10 nuts in flywheel crankcase section.

0.071 mm (0.0012-0.0028 inch) with a maximum allowable clearance of 0.2 mm (0.008 inch).

To reassemble crankshaft and crankcase, proceed as follows: Install main bearings (34 and 59) so flange is to inside of crankcase and oil hole is aligned in flywheel crankcase section bearing (59). Place thrust washer halves (48) on both sides of main bearing support halves (47 and 50) with grooved side out. Install main bearing support halves (47 and 50) on crankshaft and tighten screws (46) to 39 N·m (29 ft.-lbs.). With bearing support held towards one end of crankshaft, measure clearance between thrust rings (48) and side of crankshaft to determine crankshaft end play. Clearance should be 0.1-0.3 mm (0.004-0.012 inch). Thrust washer halves are available in standard and 0.1 mm (0.004 inch) oversize thicknesses.

Heat center crankcase to 150°C (300°F). With crankshaft pointing in correct direction, insert crankshaft into crankcase so mating line of bearing support is matched with crankcase alignment marks (M – Fig. W2-22) and immediately start support retaining screws but do not tighten.

Install connecting rods and tighten rod nuts to 34 N·m (25 ft.-lbs.). With control rod tube (39 – Fig. W2-14) and seals (38) in place, mate pto crankcase section (36) with center crankcase section (60). Install socket head screw (32 – Fig. W2-14 and W2-21) and tighten to 34 N·m (25 ft.-lbs.) only if center crankcase has cooled to ambient temperature. Mate flywheel crankcase section (56 – Fig. W2-14) with center crankcase. Tighten M8 nuts to 25 N·m (18 ft.-lbs.) and M10 nuts to 34 N·m (25 ft.-lbs.) (Fig. W2-23). If not previously tightened, tighten pto crankcase socket head screw (32 – Fig. W2-14 and W2-21) to 34 N·m (25 ft.-lbs.). Tighten main bearing support retaining screws (51 – Fig. W2-14) to 40 N·m (30 ft.-lbs.). Complete remainder of reassembly by reversing disassembly procedure.

NOTES

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